Confidential Information

COMPACT disc

Recordable Compact Disc Systems

Part I : CD-MO
Part II : CD-WO

System Descriptions
November 1990

Sony Corp.

N.V. Philips

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Confidential Information



Recordable Compact Disc Systems

Part I : CD-MO

System Description
November 1990

Sony Corp. N.V. Philips

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1. General

1.1. Scope

The CD-MO system (referred to as CD-MO after the Magneto Optic technology that is used) gives the opportunity to write and read CD information many times. Optionally there may be pre-mastered CD information present on the disc.
The CD-MO format gives the possibility for both Audio and Data recording.

1.2. General description

In the CD-MO system, the disc contains a Magneto Optic layer. In the Recordable Area of the disc, the information is recorded in this layer as differently oriented magnetic domains.
Different from the reflectivity change in e.g. CD-Audio and CD-ROM pre-mastered discs, the reading mechanism in CD-MO is a change in the polarization direction of the reflected laser beam.
The CD-MO disc contains CLV clocking information and a time code over the entire Information Area of the disc.
The Recordable Area has a wobbled pre-groove for tracking-, speed- and timing purposes.
Recording takes place in the U-shaped, wide groove.

Remark 1: All parameters mentioned in this Orange Book Part I refer to the 12 cm disc. For the 8 cm disc these parameters (e.g. diameters) should be corrected according to the parameters given in the Red Book on page 84 up to 86 (description of 8 cm CD-single).

Remark 2: When the chapter DISC SPECIFICATION of the Red Book is being referred to, the pages 74 up to 83 are excluded (description of CD-Video).

1.3. References

Red Book : Compact Disc Digital Audio system description, N.V. Philips and Sony Corporation.

Yellow Book : Compact Disc Read Only Memory (CD-ROM) system description, N.V. Philips and Sony Corporation.

Orange Book Part II : Compact Disc Write Once (CD-WO) system description, N.V. Philips and Sony Corporation.

1.4. Definitions

1.4.1. General:

- CLV : Constant Linear Velocity.

- Groove : The guidance track in which completely identical clocking and time-code information is seen at both edges.
  The pre-groove is U-shaped with (see Attachment A5):
  - a typical depth of $\lambda/9$ - $\lambda/7$
  - a typical width of 1.0 - 1.2 µm.
  Pits are U-shaped having a width of 0.45 - 0.7 µm.

- Land : Area between the grooves.
  Note: In HF measurements (e.g. jitter) 'Land' is often used as the area between pits.

- Pit : Recorded effect (I_3..I_{11} effects)

- MM : Magnetic field Modulation. The EFM encoded information is recorded on the disc by switching an external magnetic field between two opposite directions. At every transition in the EFM signal, the magnetic field is switched.

- H_{ext} : External magnetic field. The magnetic field that switches between two opposite directions (both perpendicular to the disc surface) according to the EFM encoded information. When the laser heats up the disc sufficiently, this magnetic field causes a permanent magnetic domain in the Magneto Optic layer on the disc.

- H_0 : The optimum external magnetic field. The center value of the range of external magnetic fields that will give results within spec.

- CW : Continuous Wave. The laser light output is at a constant level.

- P_0 : The optimum recording power. The center value of the range of recording powers that will give results within spec. For the measurement of P_0 see Attachment A7.

- Wobble : The pregroove in the disc is not a perfect spiral but is wobbled with:
  - a typical amplitude of 30 nm
  - a spatial period of 54 to 64 µm
  When this wobble is locked to a frequency of 22.05 kHz, the velocity of the disc should be in the range of 1.2 to 1.4 m/s.

- ATIP : Absolute Time In Pregroove. With an additional modulation of the groove wobble, the pregroove contains a time code information called ATIP (see chapter 4).

- ATER : ATIP Error Rate. Number of erroneous ATIP frames in proportion to the total number of frames.

- Jitter : The 1 σ value of the time variations between consecutive I_3 transitions (land and pit) of the unequalized HF signal (random EFM data). For the measurement of jitter, see Attachment A8.

- k : Temperature coefficient of the sensitive layer of the disc. It is expressed as the relative change in optimum recording power per degree centigrade temperature difference (%/°C).

1.4.2. Disc areas:

Remarks:
- The term RECORDED AREA of the Red Book is replaced in this document by the term Information Area.
- More information about the areas mentioned below is given in chapter 5.
- The layout of the CD-MO disc is given in figure 1.1 and 1.2.

The terms used to distinguish between the areas on the disc are:

Information Area :
The Information Area of a CD-MO disc contains CLV clocking information and a time-code.
The Information Area of the disc is divided into five parts:

1: The Lead-in Area
2: The Optional Pre-mastered Area
3: The UTOC Area
4: The Recordable User Area
5: The Lead-out Area

Lead-in Area :
The Lead-in Area contains pre-mastered information with the Table Of Contents (TOC).

Optional Pre-mastered Area :
The Optional Pre-mastered Area contains pre-mastered information with Audio and/or Data Tracks.

UTOC Area :
The UTOC (User Table Of Contents) Area contains:
- after (partial) recording: the Table Of Contents for the information Tracks in the Recordable User Area
- the Power Calibration Area
- the Reserved Area

Recordable User Area :
In the Recordable User Area the Tracks with user information are recorded. The Tracks can be both Audio Tracks and Data Tracks.

Lead-out Area :
The Lead-out Area contains pre-mastered information.

Remark:
- The Optional Pre-mastered Area together with the Recordable User Area are called: the Program Area.
- The UTOC Area together with the Recordable User Area are called: the Recordable Area.

1.4.3. Signals :

Pre-mastered signals:

The pre-mastered signals are measured with a set up as defined in the chapter DISC SPECIFICATION of the Red Book (circular polarized light should be used).

I_0 : Blank area level

I_{top} : Top level of pre-mastered I_{11} signal

I_{11}/I_{top} : Modulation amplitude of pre-mastered I_{11} signal

I_3/I_{top} : Modulation amplitude of pre-mastered I_3 signal

I_1 : Land level

I_g : Groove level
* Groove level > land level for the Recordable Area.

$RC=2|I_1-I_g|/(I_1+I_g)$: Radial Contrast
* For pre-mastered pits: I_g (resp. I_1) is defined as the averaged (τ = 15 μsec) HF signal, measured in the groove (resp. on land) before AC coupling.

$|I_1-I_2|/I_{top}$ at 0.1 μm radial offset : Push Pull amplitude for the pre-mastered pits area.
* (I_1-I_2) is measured after low-pass filtering (f < 5 kHz)
* See Red Book Chapter 15.1 for explanation.

$|I_1-I_2|/I_g$ at 0.1 μm radial offset : Push-pull amplitude for the pre-mastered grooves area (Recordable Area).
* (I_1-I_2) is measured after low-pass filtering (f < 5 kHz)
* See Red Book Chapter 15.1 for explanation.

$I_w = (I_1-I_2)$: Wobble signal
* (I_1-I_2) is measured after band-pass filtering (10 < f < 30 kHz)

$I_{w\text{-}rms}/(I_1-I_2)_{pp}$: Normalized wobble signal
* see Attachment A4

Recorded signals:

The recorded signals are measured with a standard MO differential detection set up (see Attachment A1). This implies that no polarization optics are used besides the splitter right in front of the detectors D_1 and D_2. This means that all MO-signals mentioned in this book are defined without Enhancement. See Note in Attachment A1.

I_{sum} : D1 + D2

I_{11}/I_{sum} : Modulation amplitude of recorded I_{11} signal

I_3/I_{sum} : Modulation amplitude of recorded I_3 signal

ODU = $|D1-D2|_{max}/(D1+D2)$: Optical Disc Unbalance
* D_1 and D_2 are measured after low-pass filtering (f < 100 Hz)

2. Disc specification

Standard atmospheric conditions for testing

Measurements and mechanical checks are to be carried out at any combination of temperature, humidity and air pressure within the following limits unless otherwise specified :

Ambient temperature	15°C to 35°C
Relative humidity	45% to 75%
Air pressure	86 kPa to 106 kPa

For all pre-mastered signals, an optical pick-up unit for disc measurements as defined in the Red book on page 2 should be used (circular polarized light should be used).

For the Magneto Optical signals, a Magneto Optical pick-up unit for disc measurements as defined below should be used.

The Magneto-Optical pick-up unit for disc measurements:

Optical:

Laser wavelength	780 ± 10 nm
N.A.	0.45 ± 0.01
Direction of polarization	E-vector perpendicular to pregroove
Polarization ratio on disc ($I_{\perp} / I_{//}$)	> 45
Retardation of read out optics ($\Delta P - \Delta S$)	< 10°
Wave front distortion (w.f.d.)	< 0.05 λ
Rim-intensity of the pupil	Tangential: 0.7 ± 0.1 Radial : 0.1 ± 0.05

Magnetic: (during recording)

Magnetic field perpendicular to the MO layer at laser spot position	100< H_{ext} <400 Oe
Risetime of the magnetic field (-90% to +90%)	< 200 ns

Characteristic to be specified	Requirements	Remarks
2.1. Read out system		
2.1.1. Read out mode	See Red Book page 2 chapter 1.1	
2.1.2. Track shape	See Red Book page 2 chapter 1.2	
2.1.3. Transition between pits and groove	At the transition between pits and groove the pre-mastered signals may be out of specification for a duration of $t<50$ μsec.	
2.2. Outer diameter	See Red Book page 2 chapter 2.	
2.3. Center hole	See Red Book page 2 chapter 3.	
2.4. Thickness	$1.2^{+0.12}_{-0.1}$ mm	Including protective coating and label
2.5. Clamping area		
2.5.1. Areas	See Red Book page 3 chapter 5.1	
2.5.2. Thickness	$1.2^{+0.12}_{-0.1}$	Including protective coating and label
2.5.3. Height of reference plane	See Red Book page 3 chapter 5.3	
2.6. Deflection	See Red Book page 3 chapter 6.	
2.7. Label		
2.7.1. Label diameters	See Red Book page 3 chapter 7.1	
2.7.2. Label side of disc	See Red Book page 3 chapter 7.2	

Characteristic to be specified		Requirements	Remarks
2.7.3.	Thickness of label plus protective coating	<20 µm	
2.7.4.	Label ink and coating	Must not disturb external magnetic field.	
2.8.	Optical Requirements		Within the Information Area
2.8.1.	Thickness of transparent disc substrate.	See Red Book page 3 chapter 8.1.	
2.8.2.	Refractive index of transparent substrate.	See Red Book page 3 chapter 8.2.	
2.8.3.	Optical disc unbalance	ODU < 0.05	ODU includes birefringence, See Attachment A3
2.8.4.	Reflection and double pass substrate transmission	15 < R < 30%	See Attachment A2
2.8.5.	Maximum variation of reflection and double pass substrate transmission	$\Delta R/R <$ 15% peak-peak, frequency ≤ 100 Hz	
2.8.6.	Optical quality of the disc	Wave front distortion < 0.05 λ	
2.8.7.	Inner diameter of reflective and/or sensitive layer	37 ± 4 mm	
2.8.8.	Outer diameter of reflective and/or sensitive layer	118 +2/-0 mm	For 8 cm disc: 78 +2/-0 mm
2.9.	Information Area (In the Red Book referred to as RECORDED AREA)	See Red Book page 4 Chapter 9.	
2.10.	Track pitch	See Red Book page 4 chapter 10.	

Characteristic to be specified	Requirements	Remarks
2.11. Rotation		
2.11.1. Sense of rotation	See Red Book page 4 chapter 11.1	
2.11.2. Scanning velocity	See Red Book page 4 chapter 11.2	
2.11.3. Maximum velocity variation	± 0.01 m/s	On one disc, for f < 1Hz.
2.12. Vertical deviations of the information layer	See Red Book page 5 chapter 12.	
2.13. Radial deviations of the track	See Red Book page 5 chapter 13.	
2.14. Write conditions		
2.14.1. General recording strategy	- Magnetic Field Modulation (MM) - recording in wide groove - CW recording power.	
2.14.2. Optimum recording power of a disc	P_0 in TOC	For T=25°C; for measurement of P_0 see Attachment A7.
2.14.3. Optimum recording power range for all discs	$2.5 \leq P_0 \leq 5.0$ mW	For T=25°C, CW in the central spot
2.14.4. Minimum recording power sensitivity of a disc	For $P_0 \pm 0.2P_0$, disc must be recordable within specification	For T=25°C
2.14.5. Minimum magnetic field sensitivity range	For $P_0 \pm 0.2P_0$, disc must be recordable within spec for $100 < H_{ext} < 400$ Oe	For P_0, disc must be recordable within spec for $80 < H_{ext} < 400$ Oe
2.14.6. Overwrite conditions	Equal to write conditions.	
2.14.7. Temperature dependence of recording power	$-0.7 < k < -0.3$ %/°C	

Characteristic to be specified	Requirements	Remarks
2.14.8. Wavelength sensitivity of recording power	For 770< λ <830nm the required optimum recording power of the disc must be constant within 10%	Sensitivity measured with a constant laser spot size on the disc.
2.14.9. Radial tracking	offset < 0.1 μm	- Relative to center of average pre-groove position - See chapt.2.17.
2.14.10. Overwrite ability	> 10^6 times within spec.	
2.15. <u>Read conditions</u>		
2.15.1. Power in read spot	≤ 0.7 mW	CW, in the central spot.
2.15.2. Read stability	> 10^6 times successively read from a single track, the disc should remain within spec.	For P_{read}= 0.7 mW and T=55°C
2.15.3. Radial tracking	offset < 0.1 μm	- Relative to center of average pre-groove position - See chapt.2.17.

Characteristic to be specified	Requirements		
	Pre-mastered		Recorded
	Pits	Grooves	

2.16. HF signal

Unless otherwise specified in this Orange Book Part One, the description of the HF signal in the Red Book and the Yellow Book (page 6, chapter 14.) is valid.

2.16.1. Modulation amplitude			
	I_3/I_{top}	> 0.15	-	-
	I_{11}/I_{top}	0.3 - 0.6	-	-
	I_{11}/I_{sum}	-	-	0.03 - 0.08
	I_3/I_{11}	-	-	> 0.35
2.16.2. Asymmetry		< 20%	-	< 5%
2.16.3. Block Error Rate (averaged over any 10 sec)		$< 3.10^{-2}$	-	$< 3.10^{-2}$
2.16.4. Cross talk		< 50%	-	-
2.16.5. CNR for periodic effects in the range from 200-720 kHz		-	-	> 46 dB (BW=10kHz)
2.16.6. Jitter (see chapt. 1.4.1 and Attachment A8):				< 40 ns
2.16.7. Single frequency time errors (see Attachment A8):				The spectral components of the time errors should be below the values given in Figure 2.2 (f≤4 kHz).

Characteristic to be specified	Requirements		
	Pre-mastered		Recorded
	Pits	Grooves	

2.17. Radial tracking signals

- Unless otherwise specified in this chapter, the description of the radial tracking signal in the Red Book and the Yellow Book (page 7, chapter 15.) is valid.
- For a recorder, the bandwidth of the radial servo is >700 Hz (see Figure 2.3).
- For measuring purposes the bandwidth may be specified differently.

2.17.1.	Push pull amplitude	0.04-0.11	0.11-0.20	0.11-0.20
2.17.2.	Noise in radial tracking signal	<0.02 μm_{rms}	<0.02 μm_{rms}	<0.02 μm_{rms}
2.17.3.	RC	0.15 - 0.30	0.20 - 0.35	0.20 - 0.35
2.17.4.	Variations on RC	< $\pm$15 %	< $\pm$15 %	< $\pm$15 %

2.18. Tangential tracking signals

2.18.1.	Locking frequency for groove wobble	22.05 kHz	22.05 kHz	22.05 kHz
2.18.2.	Normalized wobble signal (see Attachment A4)	-	0.035 - 0.050 (for track pitch 1.6 μm)	0.035 - 0.050 (for track pitch 1.6 μm)
2.18.3.	CNR of wobble	> 15 dB BW = 1kHz	> 35 dB BW = 1kHz	> 35 dB BW = 1kHz

2.19. Time encoding

2.19.1.	Wobble modulation	ATIP	ATIP	ATIP
2.19.2.	ATER (averaged over any 10 sec)	-	< 10%	< 10%
2.19.3.	Maximum number of successive erroneous frames	-	3 ATIP frames	3 ATIP frames

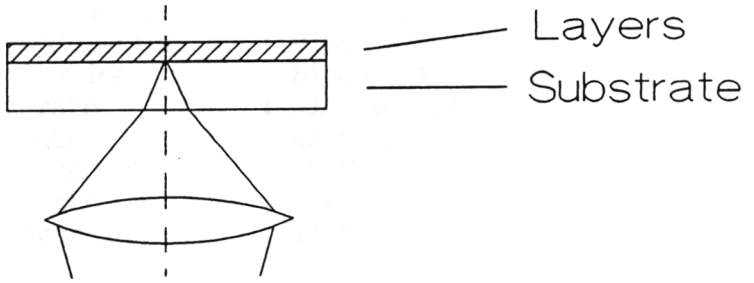
Characteristic to be specified	Requirements	Remarks
2.20. Environment (operating conditions)	Disc must be recordable and playable in all combinations given in Figure 2.1.	See Attachment A6
2.20.1. Temperature range	T = -5 to +55°C	
2.20.2. Absolute humidity	0.5 to 30 g/m^3	
2.20.3. Relative humidity	5% to 95%	

3. Optical stylus

The wavelength λ and the numerical aperture NA have to fulfill the requirement:

$$\lambda / NA \leq 1.75\ \mu m$$

The stylus should be diffraction limited. The information is viewed through a transparent, plane parallel plate of 1.2 mm thickness, with a refractive index of about 1.55.
The system is optimized for a wavelength between 0.77 and 0.83 μm (e.g. laser wavelength of Aluminum Gallium Arsenide). The depth of focus of the optical stylus is approximately 2 μm.



For further description of the optical principles of the CD-MO system, see Attachment A1.

4. Pregroove modulation

By means of ATIP (Absolute Time In Pre-groove) the CD-MO disc contains motor control information (the carrier frequency) and time-code information (modulation of the carrier frequency).
In the Lead In Area (see Chapter 5) the ATIP time code increases, and ends with the time code 99:59:74 (min:sec:frames) at the end of the Lead In Area. The area next to the Lead In Area starts with a time code 00:00:00. From this point on, ATIP time code increases monotonically and uninterrupted throughout the remainder of the disc.

4.1. General parameters

Disc	: Radial track-wobble
Analog modulation	: FM
Carrier frequency	: 22.05 kHz
Digital modulation	: Biphase-Mark
Synchronization	: Biphase violation
Data bit-rate	: 3150 Bits/Sec
Frame length	: 42 bits
Frame frequency	: 75 Hz
Data contents	: 3 Bytes (Min Sec Frames, 1 Byte each)
Error protection	: 14 bits CRC

4.2. FM modulation

Carrier frequency	: 22.05 kHz
Deviation	: 1 kHz $\pm$ 10 %
Oscillator output	: Sinewave
Oscillator THD	: < - 40 dB

4.3. Frame format

The format of one ATIP frame is :

Nr of Bits	4	8	8	8	14
Bit position	1234	111 56789012	11111112 34567890	22222222 12345678	23333333333444 90123456789012
Data	Sync	Minutes	Seconds	Frames	CRC remainder

4.3.1. Frame synchronization

For synchronization of the ATIP data the Biphase-Mark coderules are violated. The synchronization pattern used is 11101000 if the preceding cell = 0, or 00010111 if the preceding cell = 1.

Example-1 :

Wave form 

Channel-bits	0	1 1 1 0 1 0 0 0	1 1	0 1	0 1	0 1	0 0	1 1	0 1	0
Data bits		< SYNC >	0	1	1	1	0	0	1	

Example-2 :

Wave form 

Channel-bits	1	0 0 0 1 0 1 1 1	0 0	1 0	1 0	1 0	1 1	0 0	1 0	1
Data bits		< SYNC >	0	1	1	1	0	0	1	

4.4. Data format

The format of the ATIP time information is identical to the time encoding in Subcode-Q and in the CD-ROM header. The ATIP time information is represented in Binary Coded Decimal (BCD) with the most significant bit first as follows :

Minutes : 2 digits BCD, MSBit on position 5
Seconds : 2 digits BCD, MSBit on position 13
Frames : 2 digits BCD, MSBit on position 21

4.5. Error detection

The error detection method uses a 14 bits CRC on Minutes, Seconds and Frames. The CRC codeword must be divisible by the check polynomial. The most significant bit of the CRC codeword is bit-5, the least significant bit is bit 42 of the ATIP frame. The CRC parity bits (bit 29 .. 42) are inverted on the disc.

The check polynomial is :

$$P(X) = X^{14} + X^{12} + X^{10} + X^7 + X^4 + X^2 + 1$$

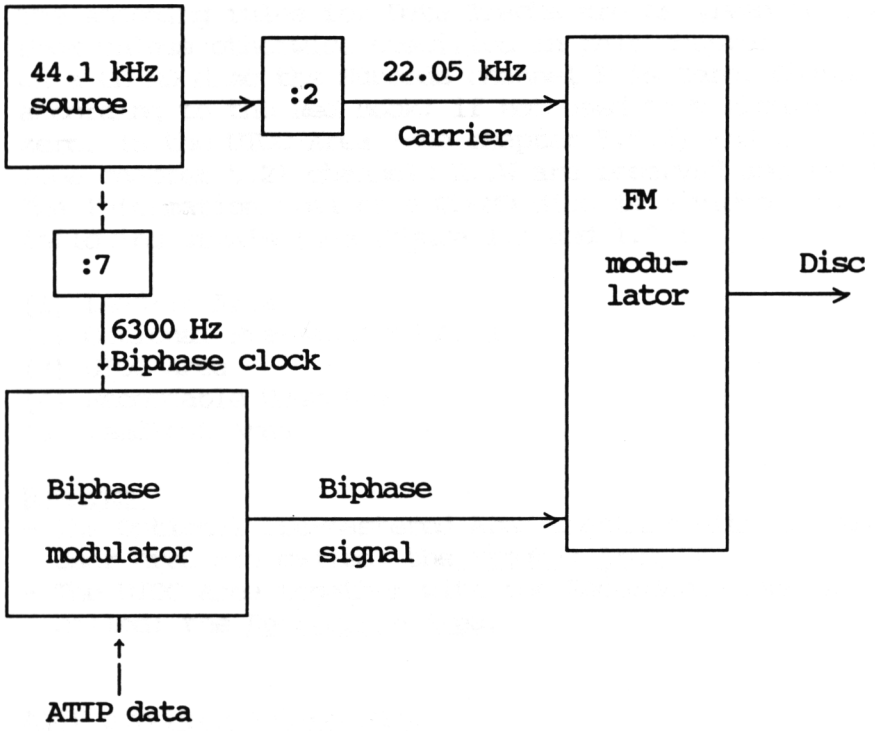
4.6. Bit rate

Bit rate = nr of addresses/sec * nr of bits/address
= 75 * 42
= 3150 bits/sec.

The bit rate is 1/7 of the 22.05 kHz wobble frequency. Both the 22.05 KHz wobble and 6.3 KHz biphase clock frequencies are derived from the same 44.1 kHz source.

4.7. ATIP encoder

The block diagram of the ATIP encoder is :



5. Data organization

The encoding rules for CD-Audio Tracks are as given in the Red Book unless otherwise specified in this chapter.
The encoding rules for Data Tracks are as given in the Yellow Book unless otherwise specified in this chapter.
On a CD-MO disc the Subcode channel P is zero. Channels R..W are according to the Red Book; if not used they should be set to zero. In the UTOC Area (see chapter 5.5.2) and the Lead In Area (see chapter 5.2) channels R..W are reserved and set to zero.
The Information Area of a CD-MO disc is divided into the following area's (see Figure 1.1 and 1.2):

(1) Lead-in Area
(2) Optional Pre-mastered Area
(3) UTOC Area
(4) Recordable User Area
(5) Lead-out Area

Remarks:
- The Optional Pre-mastered Area together with the Recordable User Area are called: the Program Area.
- The UTOC Area together with the Recordable User Area are called: the Recordable Area.

5.1. ATIP synchronization rule

On the whole disc the allowed tolerance between the position of the ATIP sync and the Subcode sync is ± 10 EFM frames.
The position of a ATIP-sync is defined as the position where a sync can be determined as a sync-pattern; this means directly after the physical sync pattern on the disc.
The position of a Subcode-sync is defined as the start-position of the physical sync pattern on the disc (see fig. 5.1).

5.2. Lead-in Area

During the Lead-in Area, the disc contains ATIP data and pre-mastered EFM.
It is recommended that during the Lead-in Area the data words are 2-Complement Zero ±15 LSB.
The pre-mastered EFM contains a Table Of Contents (TOC) in Subcode channel-Q (see Fig. 5.2 and 5.3). The format of the TOC has a high degree of compatibility with the TOC defined in the Red Book and the Yellow Book.
Within the Lead-in Area the data format of Subcode channel-Q is:

S0, S1	CON TROL	1	00	POINT	MIN	SEC	FRAME	ZERO	PMIN	PSEC	P-FRAME	CRC
		ADR	TNO									

The coding rules for S0, S1, CONTROL, MIN, SEC, FRAME, ZERO and CRC are given in the Red Book and in the Yellow Book.
In the TOC the Items are repeated three times each. The complete TOC is continuously repeated during the Lead-in Area.

5.2.1. POINT = 01 .. 99
The value of PMIN, PSEC and PFRAME gives the start position of the pre-mastered Track (if present) pointed to by POINT.

5.2.2. POINT = A0
The value of PMIN gives the value of the first track number in the Optional Pre-mastered Area. If the Optional Pre-mastered Area is not available on a disc, PMIN is zero. If the Optional Pre-mastered Area is available on a disc, PMIN is always 01 indicating the first track in the Optional Pre-mastered Area.
The value of PSEC is 01, indicating a recordable disc.
The value of PFrame is zero.

5.2.3. POINT = A1
The value of PMIN gives the value of the last Track number in the Optional Pre-mastered Area. If the Optional Pre-mastered Area is not available on a disc, PMIN is zero.
The value of PSEC is zero.
The value of PFRAME is zero.

5.2.4. POINT = A2
The value of PMIN, PSEC and PFRAME gives the start position of the Lead-out Area.

5.2.5. POINT = A3
The value of PMIN, PSEC and PFRAME gives the start position of the first Item of the User Table Of Contents in the UTOC Area.
The time-code given by this value of POINT is: the highest value of ATIME in the Optional Pre-mastered area plus 1 second, if this area is present. If the Optional Pre-mastered Area is not present, the value is 00:01:00.

5.2.6. POINT = A4
The value of PMIN, PSEC and PFRAME gives the start position of the Recordable User Area.
The time-code given by this value of POINT is: the value of POINT =A3 plus 29 seconds.

5.2.7. POINT = FF
The bytes PMIN, PSEC and PFRAME contain disc parameters.

PMIN :

MSB							LSB
7	6	5	4	3	2	1	0

Bit-7 = 0 : reserved
= 1 : CD-MO disc

Bit-6 = 0 : 12 cm disc
= 1 : 8 cm disc

Bit-5..Bit-0 = 000000 : reserved

PSEC :

MSB							LSB
7	6	5	4	3	2	1	0

Bit-7..Bit-5 = 000 : CW laser power
= 001..111 : Reserved

Bit-4 = 0 : Reserved

Bit-3..Bit-0 : recommended optimum recording power P_0 in mW at T=25°C

= 0000 : 2.5 mW
= 0001 : 2.6
= 0010 : 2.7
= 0011 : 2.85
= 0100 : 3.0
= 0101 : 3.15
= 0110 : 3.3
= 0111 : 3.45
= 1000 : 3.6
= 1001 : 3.75
= 1010 : 3.95
= 1011 : 4.15
= 1100 : 4.35
= 1101 : 4.55
= 1110 : 4.75
= 1111 : 5.0

PFRAME :

MSB							LSB
7	6	5	4	3	2	1	0

Bit-7..Bit-0 = 00000000 : Reserved

5.2.8. ATIP/Subcode synchronization
In the Lead-in Area the ATIP time-code is identical to the time value encoded in MIN, SEC, FRAME of Subcode channel-Q.
The end of the Lead-in Area is encoded with a time-code of 99 Minutes, 59 Seconds, 74 Frames in both ATIP and Subcode-Q.

5.3. Program Area
The Program Area consists of the Optional Pre-mastered area and the Recordable User Area.

5.3.1. ATIP/Subcode synchronization
In the Program Area the ATIP time-code is identical to the Subcode-Q absolute time (AMIN, ASEC, AFRAME).
The first ATIP and Subcode-Q time-code in the Program Area is 00:00:00 (min:sec:frames) when the Optional Pre-mastered Area is present. The time code is 00:30:00 when no Optional Pre-mastered Area is present.

5.4. Optional Pre-mastered Area

During the Optional Pre-mastered Area, the disc contains ATIP and pre-mastered EFM.
The pre-mastered EFM contains Tracks with user information (Audio Tracks and/or Data Tracks).
The Optional Pre-mastered Area starts at the end of the Lead-in Area. The Optional Pre-mastered Area contains Audio Tracks according to the Red Book and/or Data Tracks according to the Yellow Book.

5.4.1. Subcode/Header synchronization

For the synchronization rules between the Header address and the Subcode-Q absolute time, see the definitions in the Yellow Book.

5.5. Recordable Area

The Recordable Area consists of the UTOC Area and the Recordable User Area.

5.5.1. Linking rules

5.5.1.1. General Linking rules

The Link Position is the physical location on the disc where the recording of EFM signals is allowed to start and stop.
The nominal Link Position is 26 $\pm$ 10 EFM frames after a ATIP sync pattern (detected). As a result of this an overwriting or a gap of maximum 20 EFM frames can occur and is allowed.

5.5.1.2. Data Linking rules

At the start of EFM recording within a Data Track, a link Block and 2 run-in Blocks are recorded. At the end of the EFM recording within a Data Track, 2 run-out blocks and the start of a link Block are recorded.
In a Data Track the 3 most significant bits of the Mode byte (in the Block Header, see Yellow Book page 101) are used for run-in and run-out indication.

The layout of the Mode byte is:

	MSB							LSB
Mode :	7	6	5	4	3	2	1	0

Bit-7..Bit-5 : Run-in/out indicator
Bit-4..Bit-2 = 000 : Reserved
Bit-1..Bit-0 : The "Yellow Book MODE"
= 00 : Zero Mode
= 01 : Mode-1
= 10 : Mode-2

The codes for the Run-in/out indicator are :

0 = 000 : Blocks with user data
6 = 110 : The first run-out block
7 = 111 : The second (and last) run-out block (preceding the Link Block)
3 = 011 : The Link Block, this is the Block with its address identical to the ATIP time-code at which the physical EFM recording is started and/or stopped.
2 = 010 : The first run-in block (following the Link Block)
1 = 001 : The second (and last) run-in block
4 = 100 : Reserved
5 = 101 : Reserved

5.5.2. UTOC Area

Throughout the UTOC Area, the disc contains ATIP data, a pre-groove and (after recording) recorded EFM.

The UTOC Area contains the **Table Of Contents** for the Recordable User Area in Subcode channel-Q, a **Reserved Area** for features to be defined in future and a **Power Calibration Area.** In the UTOC Area the main channel contains audio silence (preferred 2-Complement zero ±15 LSB).

The UTOC Area starts at the end of the pre-mastered area.
The first Item of the UTOC starts 1 second after the beginning of the UTOC Area.

It is not allowed to record any signals into the first 1 second of the UTOC Area.

The size of the UTOC Area is 30 Seconds.
The User Table Of Contents requires to reserve an area of 16 seconds. The Power Calibration Area is defined as 1 second. The remaining space in the UTOC area is reserved.

In the UTOC Area the start of EFM recording is according to the linking rules of the Recordable Area.

The UTOC must be updated before the disc leaves the recorder.

5.5.2.1. Subcode-Q

The UTOC is encoded in Subcode channel-Q using TNO=0A. The UTOC contains Items, which are one subcode frame long, and which are identified by the value of POINT. An Item in the UTOC is repeated ten times in ten successive subcode frames, before a new Item (a new value of POINT) starts. See Figure 5.5 and 5.6. The first Item in the UTOC starts at the time given in the TOC at POINT=A3. As the sequence of the different Items (different values of POINT) is fixed too, the start of every possible Item (present or not) in the UTOC is at a fixed ATIME. The sequence of the different POINTers is: B-pointers, Track number-pointers, C-pointers, D-pointers.

Start times of the pointers in the UTOC:

POINT	Start time
B0	A3
01	A3 + 40 frames
..	..
99	A3 + 1020 frames
C0	A3 + 1030 frames
D0	A3 + 1050 frames

The entire User Table of Contents is not repeated.
Within the UTOC Area the data format of Subcode channel-Q is :

S0, S1	CON TROL	1	0A	POINT	MIN	SEC	FRAME	ZERO	PMIN	PSEC	P-FRAME	CRC
	ADR	TNO										

The coding rules for S0, S1, and CRC are given in the Red Book and in the Yellow Book.
Examples of the UTOC are given in fig. 5.5 and fig. 5.6

5.5.2.2. B-POINTERS

MIN, SEC and FRAME during the B-pointers (POINT = B0 .. B3) contain absolute time in line with ATIP.
CONTROL is preferred to be 0000.
ZERO is 00000000.

a) POINT = B0
POINT = B0 is the first item of the UTOC. The value of PMIN gives the lowest track number of the Recordable User Area. This value of PMIN is the value of PMIN at POINT A1 plus 1. PSEC is the number of C-pointers. In case the optional disc label is present, this value is 2, indicating that POINT C0 and C1 are present.
PFRAME is the number of D-pointers. In case the optional Disc-FTS table is present, this value indicates the number of pointers used in this table.

b) POINT = B1
The value of PMIN gives the highest track number of the Recordable User Area.
PSEC and PFRAME should be 00.

c) POINT = B2
The value of PMIN, PSEC and PFRAME gives the stopping point of the most outer recorded EFM area in the Recordable User Area.

d) POINT = B3
The value of PMIN, PSEC and PFRAME gives the stopping point of the latest recorded track in the Recordable User Area.

5.5.2.3. TRACKPOINTERS : POINT = 01 .. 99

a) The value of PMIN, PSEC and PFRAME gives the start position of the recorded user Track pointed to by POINT.
b) The value of MIN, SEC and FRAME gives the stop position of the recorded user Track pointed to by POINT.
c) The CONTROL field is defined as in Red Book on page 41 and refers to the track indicated by POINT.
d) ZERO-byte : the MSB of the ZERO-byte indicates a write-protection.
   bit 7 = 0 : (over)write protected
   = 1 : (over)write permitted
   bit 6..0 = 0000000, reserved.

5.5.2.4. C-POINTERS

POINT = C0 .. C1
Optional Disc Label of 14 ASCII Characters (Character 0..13).
The Q channel data is (n=0..1) :

S0, S1	CON TROL	1	0A	Cn	Char 7n	Char 7n+1	Char 7n+2	Char 7n+3	Char 7n+4	Char 7n+5	Char 7n+6	CRC
	ADR	TNO	POINT									

CONTROL is preferred to be 0000

5.5.2.5. D-POINTERS

POINT = D0 .. DE
The Disc FTS table contains the sequence in which the tracks are played back.
The number of pointers is specified at PFRAME of POINT = B0. The maximum number for the disc-table is 15. (n=E).

The Q channel data is (n=0..14) :

S0, S1	CON TROL	1	0A	Dn	Tno 7n	Tno 7n+1	Tno 7n+2	Tno 7n+3	Tno 7n+4	Tno 7n+5	Tno 7n+6	CRC
	ADR	TNO	POINT									

CONTROL is preferred to be 0000

If a FTS is shorter than a multiple of 7, the parameters to be added are FF.

e.g.: on the disc are 15 tracks : 1..15
the FTS is 4,6,3,10,12,4,9,1,7 ;
tracks 2, 5, 8, 11, 13, 14, 15 are not selected.
The FTS table will be :

CON/ADR	TNO	POINT	TIME	ZERO	PTIME	CRC
01	0A	D0	04 06 03	10	12 04 09	CRC
01	0A	D1	01 07 FF	FF	FF FF FF	CRC

5.5.3. Power Calibration Area
In this area the player can perform write-tests to determine optimum write-power.
This area starts 16 seconds after the time given in POINT = A3

of the TOC.
For the Power Calibration Area (PCA) 1 second is reserved.
Data in this area is not defined.

5.6. Recordable User Area

Throughout the Recordable User Area, the disc contains ATIP data, a pre-groove and (after recording) recorded EFM. The recorded EFM in this area contains Tracks with user recorded information.
The Recordable User Area starts at the time given in the TOC with POINT=A4.
The first Track Number used in the Recordable User Area is given by the value of PMIN from the TOC with POINT = A1 plus one (the number of the last Track in the Optional Pre-mastered Area plus one).
In the Recordable User Area the start of EFM recording must be at a Link-position.

5.6.1. For audio applications only:

At least 1 interleave length of digital silence is recommended at the beginning and at the end of a sequence of EFM recording.

5.6.2. Q channel data in the Recordable User Area :

S0, S1	CON TROL	1	EE	01	00	00	00	ZERO	AMIN	ASEC	A-FRAME	CRC
		ADR	TNO	INDEX	MIN	SEC	FRAME					

S0, S1, CONTROL, CRC : coding rules are according to the Red Book and the Yellow Book.

TNO, INDEX, MIN, SEC, FRAME: because of the re-recording capability they should be recorded as EE, 01, 00, 00, 00. They must be managed in the UTOC only.

AMIN, ASEC and AFRAME should be copied from ATIP.

ZERO = 0000 0000 : Original.
= 0001 0000 : First or higher generation copy of a copy-right protected track.
= else : reserved.

Recommendations:

* It is recommended to have automatic track renumbering after a recording (See figure 5.4). Track numbers must be sequential (and related to the physical track).
* Track (re)numbering is first done in μ-Controller RAM only.
* Track numbers can be edited by the users.
* Part of the subcode Q-data on the disc is not copied directly to the U-data of the Digital Audio Interface (see Red Book addition). The μController sets the correct tracknumber on TNO-position. CONTROL, ZERO, AMIN, ASEC and AFRAME must always be a copied directly to the DAI without any changes.

5.6.3. Data Tracks

A Data Track starts with a two seconds pause encoding. The data during this pause encoding is block structured and the Mode number is equal to the Mode number used in the other parts of this Track.
A blank area (no EFM data recorded) can exist within a Data Track.
Remark: Every Data Track can optionally start with a Pre Gap (including the Track Descriptor Block) as described in chapters 5.6.5.1 to 5.6.5.4 in Part II of the Orange Book.

5.6.4. ATIP/Header synchronization

The start of a Block-Sync (before encoding) is within -10 and +36 EFM frames after the (detected) ATIP Sync. (see Fig. 5.1).

5.7. Lead-out Area

Throughout the Lead-out Area, the disc contains ATIP data and pre-mastered EFM.
The pre-mastered EFM in the Lead-out Area is encoded according to the rules given in the Red Book.

5.7.1. ATIP/Subcode synchronization

In the Lead-out Area the ATIP time-code is identical to the Subcode-Q absolute time (AMIN, ASEC, AFRAME).

6. EFM Modulation system

See Red Book pages 13 up to and including 26.

7. CIRC Error correction system

Audio tracks : See Red Book pages 27 up to and including 38.
Data tracks : See Yellow Book pages 27 up to and including 38.

8. Control and display system

Audio tracks : See Red Book "CONTROL AND DISPLAY SYSTEM".
Data tracks : See Yellow Book "CONTROL AND DISPLAY SYSTEM".

9. Audio specification

See Red Book pages 1 and 1a.

10. Digital data structure

See Yellow Book pages 1, 1a and 100 up to and including 112.

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FIGURES and tables

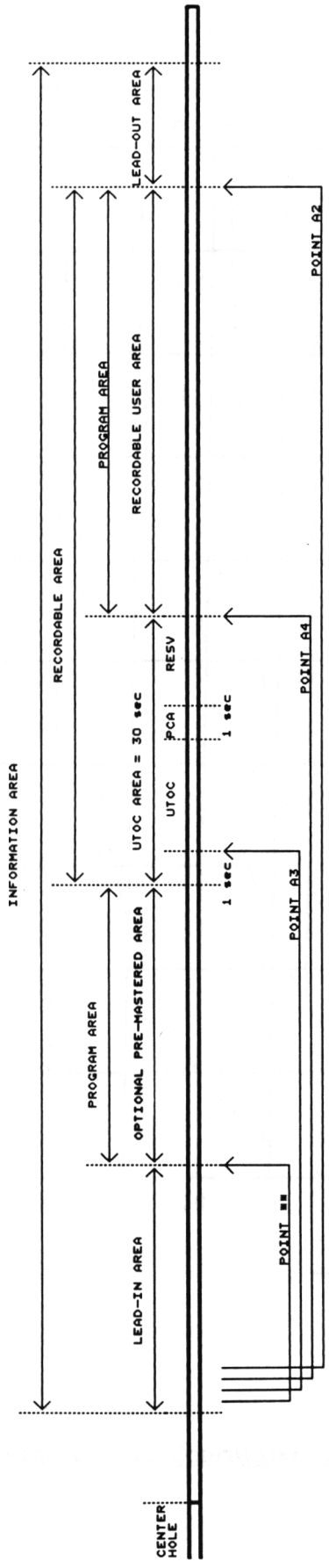


Figure 1.1 : General layout of the MO disc

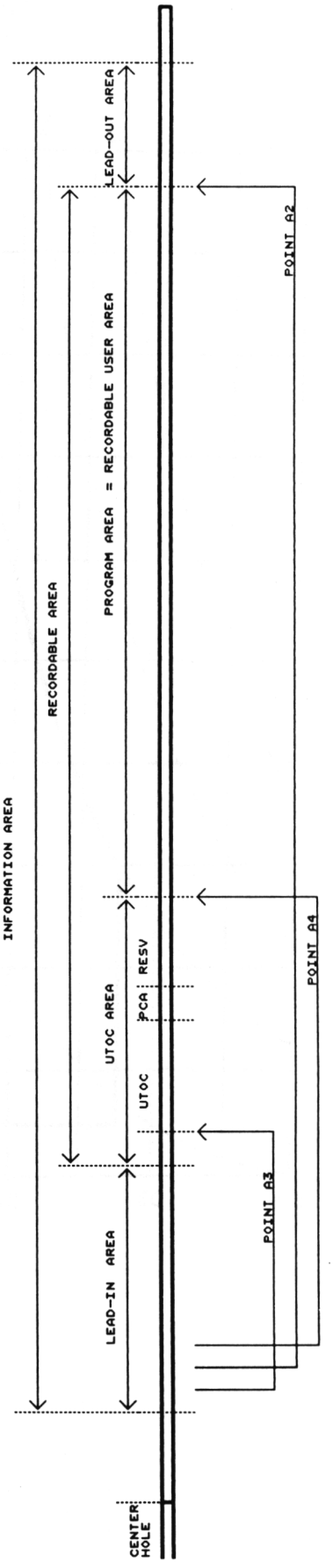


Figure 1.2 : Layout of the MO disc without the Pre-mastered Area.

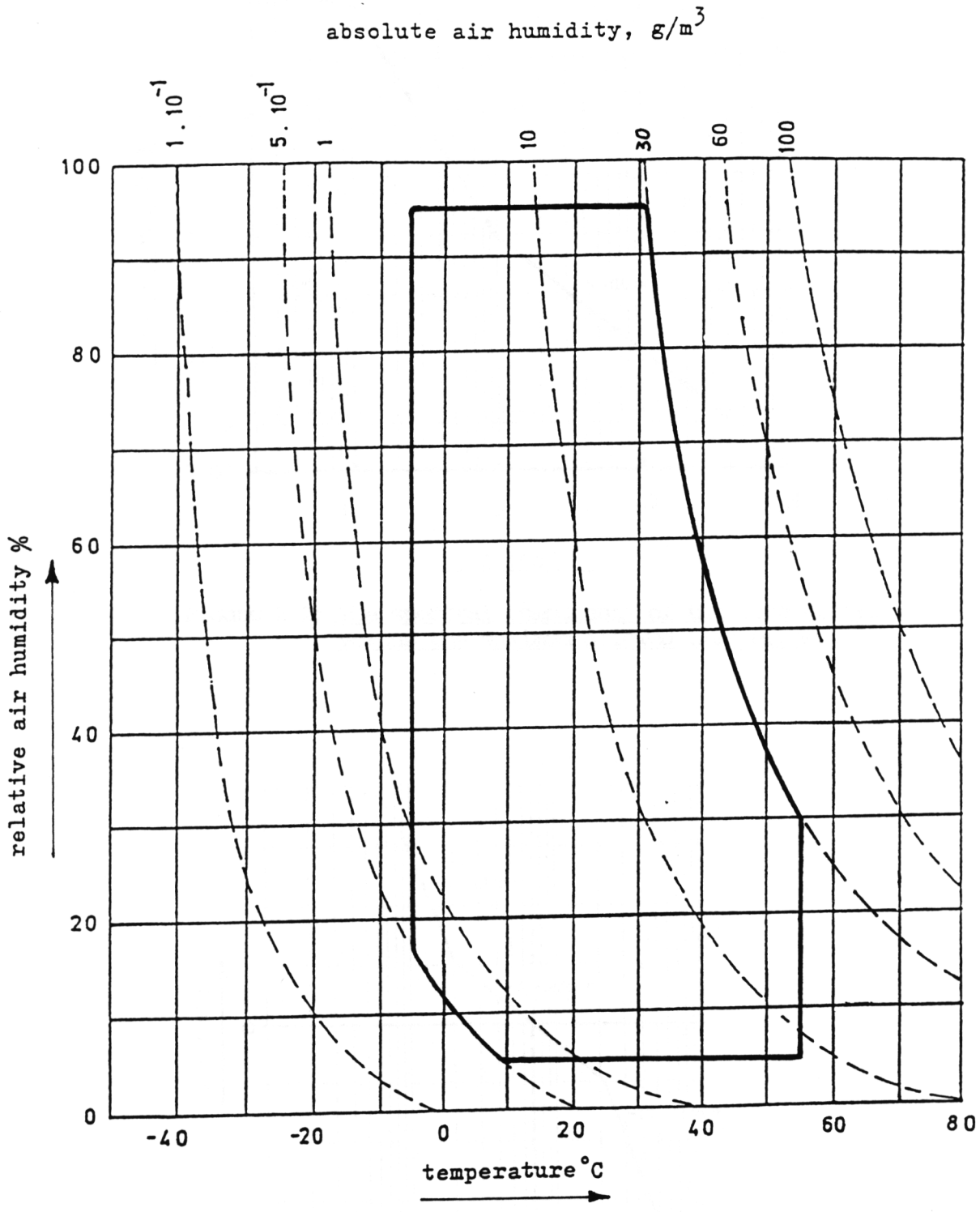


Figure 2.1: Operating conditions.

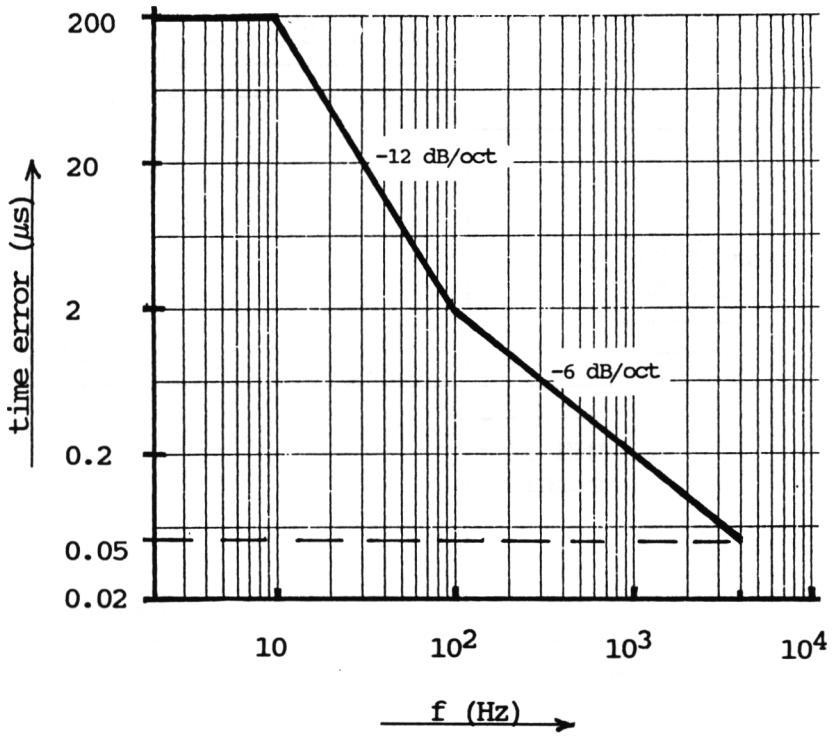


Figure 2.2: The spectral components of the time errors versus the maximum allowed time errors.

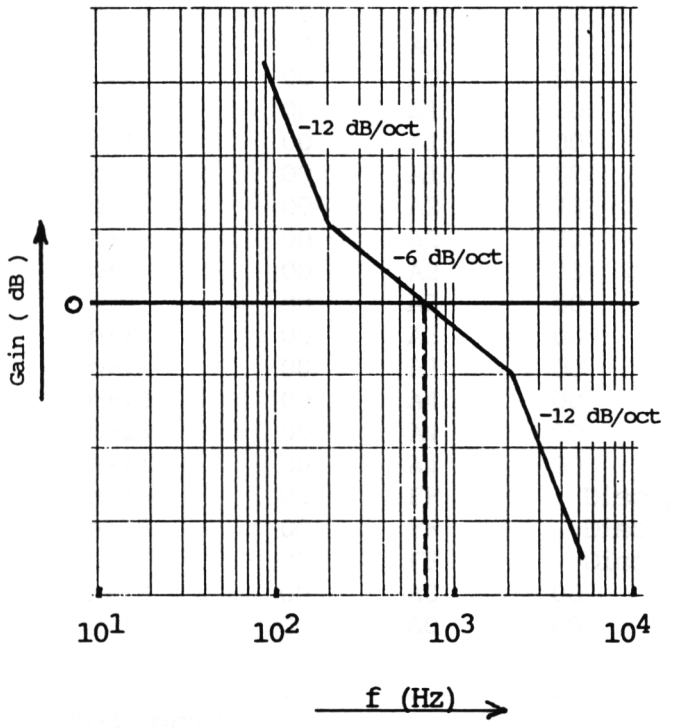


Figure 2.3: Schematic open loop transfer function of the radial servo for an MO-recorder.

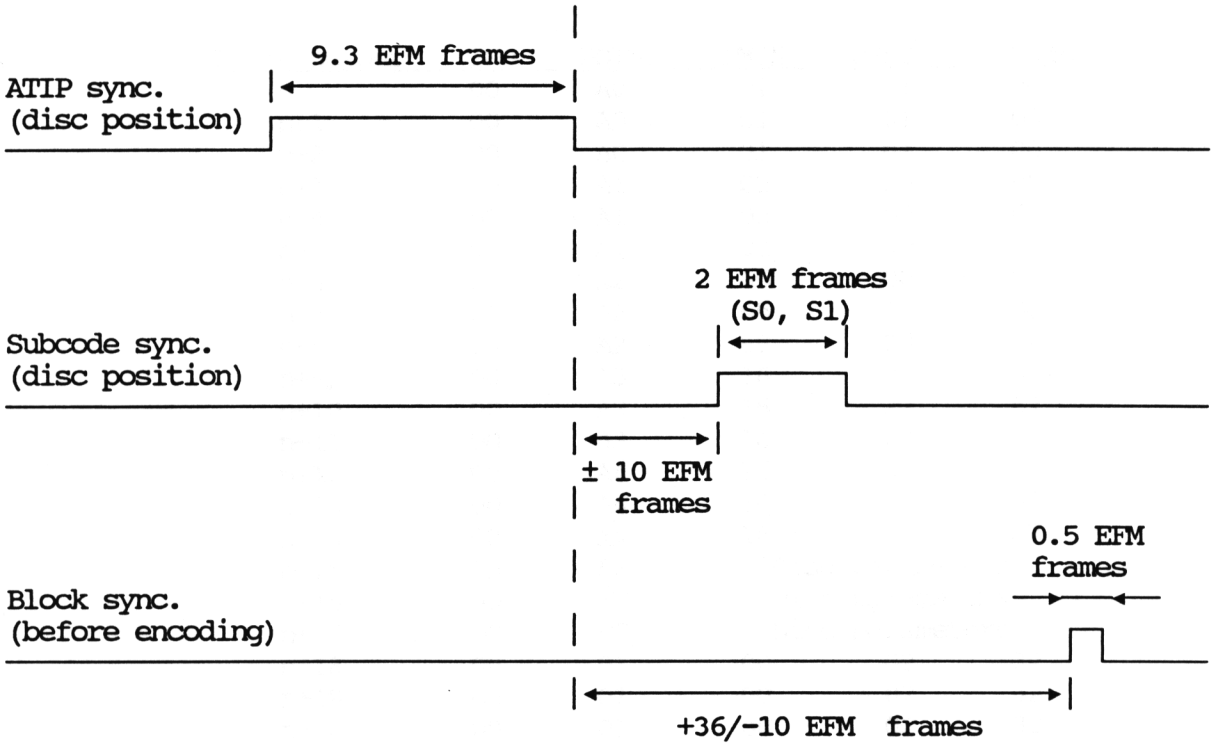


Figure 5.1: Synchronization rules.

Frame number	TNO	POINT	PMIN	PSEC	PFRAME
n	00	A0	00	01	00
n+1	00	A0	00	01	00
n+2	00	A0	00	01	00
n+3	00	A1	00	00	00
n+4	00	A1	00	00	00
n+5	00	A1	00	00	00
n+6	00	A2	73	12	09
n+7	00	A2	73	12	09
n+8	00	A2	73	12	09
n+9	00	A3	00	01	00
n+10	00	A3	00	01	00
n+11	00	A3	00	01	00
n+12	00	A4	00	30	00
n+13	00	A4	00	30	00
n+14	00	A4	00	30	00
n+15	00	FF	Disc parameters		
n+16	00	FF	Disc parameters		
n+17	00	FF	Disc parameters		
n+18	00	A0	00	01	00
n+19	00	A0	00	01	00
.	.	.	.	.	.
.	.	.	.	.	.

Figure 5.2 TOC format
Example of the encoding of the TOC of a disc without the Optional Pre-mastered Area.

Frame number	TNO	POINT	PMIN	PSEC	PFRAME
n	00	A0	01	01	00
n+1	00	A0	01	01	00
n+2	00	A0	01	01	00
n+3	00	A1	02	00	00
n+4	00	A1	02	00	00
n+5	00	A1	02	00	00
n+6	00	A2	65	00	00
n+7	00	A2	65	00	00
n+8	00	A2	65	00	00
n+9	00	A3	16	27	57
n+10	00	A3	16	27	57
n+11	00	A3	16	27	57
n+12	00	A4	16	56	57
n+13	00	A4	16	56	57
n+14	00	A4	16	56	57
n+15	00	FF	Disc parameters		
n+16	00	FF	Disc parameters		
n+17	00	FF	Disc parameters		
n+18	00	01	00	02	32
n+19	00	01	00	02	32
n+20	00	01	00	02	32
n+21	00	02	10	15	12
n+22	00	02	10	15	12
n+23	00	02	10	15	12
n+24	00	A0	01	01	00
n+25	00	A0	01	01	00
.	.	.	.	.	.
.	.	.	.	.	.
.	.	.	.	.	.

Figure 5.3 TOC format
Example of the encoding of the TOC of a disc with 2 tracks in the Optional Pre-mastered Area.

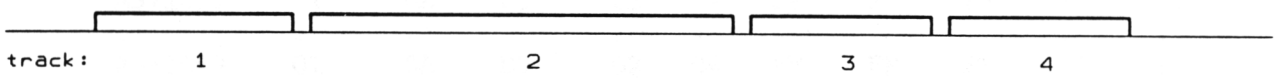


Figure 5.4 a : Track numbering before over-write

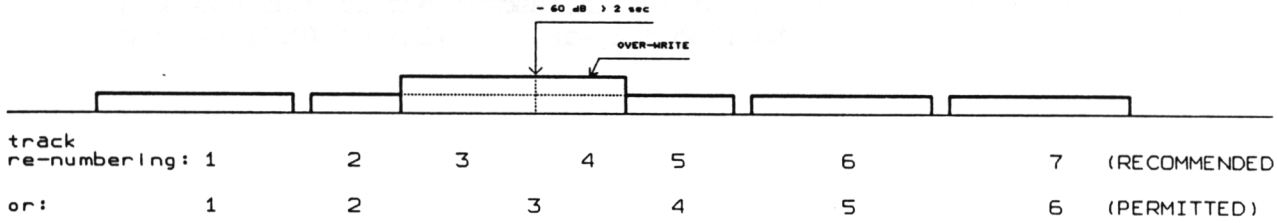


Figure 5.4 b : Track-renumbering after over-write

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
A3	01	0A	B0	12	01	00	00	03	01	01
A3+ 1	01	0A	B0	12	01	01	00	03	01	01
.	.	.	.	.	.	.	.	.	.	.
A3+ 9	01	0A	B0	12	01	09	00	03	01	01
A3+ 10	01	0A	B1	12	01	10	00	05	00	00
A3+ 11	01	0A	B1	12	01	11	00	05	00	00
.	.	.	.	.	.	.	.	.	.	.
A3+ 19	01	0A	B1	12	01	19	00	05	00	00
A3+ 20	01	0A	B2	12	01	20	00	49	40	30
A3+ 21	01	0A	B2	12	01	21	00	49	40	30
.	.	.	.	.	.	.	.	.	.	.
A3+ 29	01	0A	B2	12	01	29	00	49	40	30
A3+ 30	01	0A	B3	12	01	30	00	35	00	45
A3+ 31	01	0A	B3	12	01	31	00	35	00	45
.	.	.	.	.	.	.	.	.	.	.
A3+ 39	01	0A	B3	12	01	39	00	35	00	45
A3+ 60	01	0A	03	15	00	24	00	12	30	01
A3+ 61	01	0A	03	15	00	24	00	12	30	01
.	.	.	.	.	.	.	.	.	.	.
A3+ 69	01	0A	03	15	00	24	00	12	30	01
A3+ 70	41	0A	04	35	00	45	00	15	00	25
A3+ 71	41	0A	04	35	00	45	00	15	00	25
.	.	.	.	.	.	.	.	.	.	.
A3+ 79	41	0A	04	35	00	45	00	15	00	25
A3+ 80	01	0A	05	49	40	30	80	35	00	46
A3+ 81	01	0A	05	49	40	30	80	35	00	46
.	.	.	.	.	.	.	.	.	.	.
A3+ 89	01	0A	05	49	40	30	80	35	00	46
A3+1030	01	0A	C0	54	68	6F	6C	65	6E	20
A3+1031	01	0A	C0	54	68	6F	6C	65	6E	20
.	.	.	.	.	.	.	.	.	.	.
A3+1039	01	0A	C0	54	68	6F	6C	65	6E	20
A3+1050	01	0A	D0	02	04	FF	FF	FF	FF	FF
A3+1051	01	0A	D0	02	04	FF	FF	FF	FF	FF
.	.	.	.	.	.	.	.	.	.	.
A3+1059	01	0A	D0	02	04	FF	FF	FF	FF	FF

Figure 5.5: UTOC format

Example of encoding of the UTOC of a disc with 2 tracks in the Optional Pre-mastered Area and 3 tracks in the Recordable User Area. (The contents of the frames (A3+40) to (A3+59), (A3+90) to (A3+1029) and (A3+1040) to (A3+1049) are not defined).

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
A3	01	0A	B0	00	01	00	00	01	01	01
A3+ 1	01	0A	B0	00	01	01	00	01	01	01
.	.	.	.	.	.	.	.	.	.	.
A3+ 9	01	0A	B0	00	01	09	00	01	01	01
A3+ 10	01	0A	B1	00	01	10	00	03	00	00
A3+ 11	01	0A	B1	00	01	11	00	03	00	00
.	.	.	.	.	.	.	.	.	.	.
A3+ 19	01	0A	B1	00	01	19	00	03	00	00
A3+ 20	01	0A	B2	00	01	20	00	49	40	30
A3+ 21	01	0A	B2	00	01	21	00	49	40	30
.	.	.	.	.	.	.	.	.	.	.
A3+ 29	01	0A	B2	00	01	29	00	49	40	30
A3+ 30	01	0A	B3	00	01	30	00	35	00	45
A3+ 31	01	0A	B3	00	01	31	00	35	00	45
.	.	.	.	.	.	.	.	.	.	.
A3+ 39	01	0A	B3	00	01	39	00	35	00	45
A3+ 40	01	0A	01	15	00	40	00	00	30	01
A3+ 41	01	0A	01	15	00	40	00	00	30	01
.	.	.	.	.	.	.	.	.	.	.
A3+ 49	01	0A	01	15	00	40	00	00	30	01
A3+ 50	41	0A	02	35	00	45	00	15	00	41
A3+ 51	41	0A	02	35	00	45	00	15	00	41
.	.	.	.	.	.	.	.	.	.	.
A3+ 59	41	0A	02	35	00	45	00	15	00	41
A3+ 60	01	0A	03	49	40	30	80	35	00	46
A3+ 61	01	0A	03	49	40	30	80	35	00	46
.	.	.	.	.	.	.	.	.	.	.
A3+ 69	01	0A	03	49	40	30	80	35	00	46
A3+1030	01	0A	C0	54	68	6F	6C	65	6E	20
A3+1031	01	0A	C0	54	68	6F	6C	65	6E	20
.	.	.	.	.	.	.	.	.	.	.
A3+1039	01	0A	C0	54	68	6F	6C	65	6E	20
A3+1050	01	0A	D0	01	03	FF	FF	FF	FF	FF
A3+1051	01	0A	D0	01	03	FF	FF	FF	FF	FF
.	.	.	.	.	.	.	.	.	.	.
A3+1059	01	0A	D0	01	03	FF	FF	FF	FF	FF

Figure 5.6: UTOC format

Example of encoding of the UTOC of a disc with no tracks in the Optional Pre-mastered Area and 3 tracks in the Recordable User Area. (The contents of the frames (A3+70) to (A3+1029) and (A3+1040) to (A3+1049) are not defined).

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ATTACHMENT A: Recommendations and clarifications for the CD-MO system.

A1. Principles of operation.

Pre-mastered information:

- The pre-mastered part of the disc contains a spiral shaped track, consisting of narrow shallow depressions, called pits, in a Magneto Optic (MO) layer. The encoded Audio or Data information is stored in the length of these pits and in the distance between them. In the digital system these lengths and distances only take discrete values.
- During playback the scanning light spot is diffracted by the pits in the MO layer. The optical power that is diffracted back into the objective lens, is modulated according to the encoded Audio or Data information. The modulated photo current is called the high frequency signal (HF signal).

Recorded information:

In the Recordable Area, the disc contains a spiral shaped groove in the MO layer.
The recording of the information takes place in this U-shaped, wide groove:

> The MO layer of the disc is heated up locally by a CW laser spot. At this heated area a magnetic field is present which is modulated in two opposite directions by the information that should be recorded. In this way differently oriented magnetic domains are formed in the MO layer.

The encoded Audio or Data information is stored in the length of these domains and in the distance between them.
Read out of the recorded information with a polarized scanning light spot is based on the Magneto Optic Kerr effect:

> Depending on the magnetization direction of the domains, the polarization direction of the reflected scanning light spot rotates.

A differential detection set-up is used to transform this rotation of polarization direction into a modulated current:

> The reflected scanning light spot is reflected back into the objective lens, is divided in two equal parts by a polarization dependant splitter, and then measured by two detectors. The difference in the two photo currents is modulated according to the encoded Audio or Data information.

This resulting modulated current is called the high frequency signal (HF MO).

Note: All MO signals described in this Book are defined without Enhancement (The use of polarization dependent optics in order to improve MO system performance). If Enhancement is used, all MO signals should be corrected, in order to compare the signals correctly with the values mentioned in this Book.

Tracking Information:

An off-track position of the scanning spot results in a diffraction pattern that is asymmetrical in the radial direction of the disc. Subtraction of the powers diffracted into the two halves of the aperture of the objective lens yields a servo signal for track following.

A2. Measurement of the disc reflectivity.

The reflectivity of a CD-MO disc is measured on a set-up as given in Fig A2.1. The requirements for this set-up are in the Red Book on page 2. Non polarizing optics should be used.
A small detector is used (e.g. as in a normal player).

Note: Because of this small detector, the light reflected at the substrate, and the multiple reflections in the substrate are not included in reflectivity measurements.
When a different set-up than the above mentioned is used (e.g. parallel beam, large area detector, different wavelength, ...), compensations should be made to obtain the correct reflectivity.

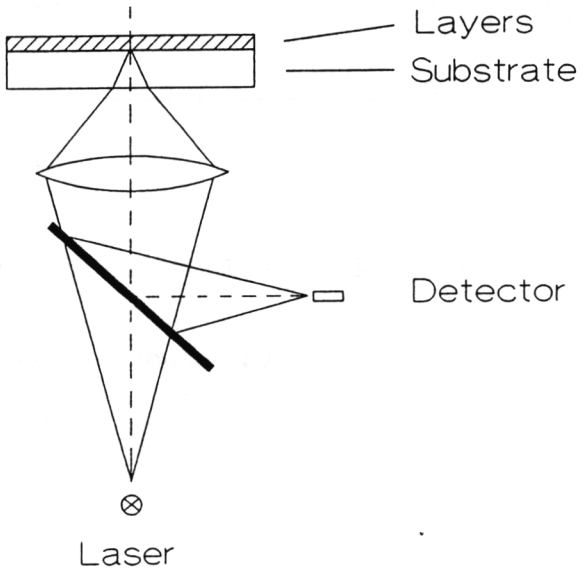


Fig A2.1: Schematic set-up for reflectivity measurements.

The reflectivity of a CD-MO disc can be measured routinely by:

1: Comparing the I_0 value of the disc to be investigated with the I_0 value of a reference disc.

2: Comparing the I_{top} value of the disc to be investigated with the I_{top} value of a reference disc:
-- When I_{top} is nearly equal to I_0 for both discs, this gives sufficiently accurate values for the reflectivity.
-- When I_{top} for one of the two discs, or for both discs is not nearly equal to I_0, then the ratios I_{top}/I_0 should be obtained. The measured reflectivity should be corrected according to these ratios, unless they are equal.

A3. Measurement of the Optical Disc Unbalance.

Birefringence of the substrate is one of the causes of an unbalance in the Magneto Optic read out signal D_1-D_2 in a CD-MO system. For optimum system performance, this low frequent ($f<100Hz$, DC coupled) signal D_1-D_2 should be close to zero (see figure A3.1).

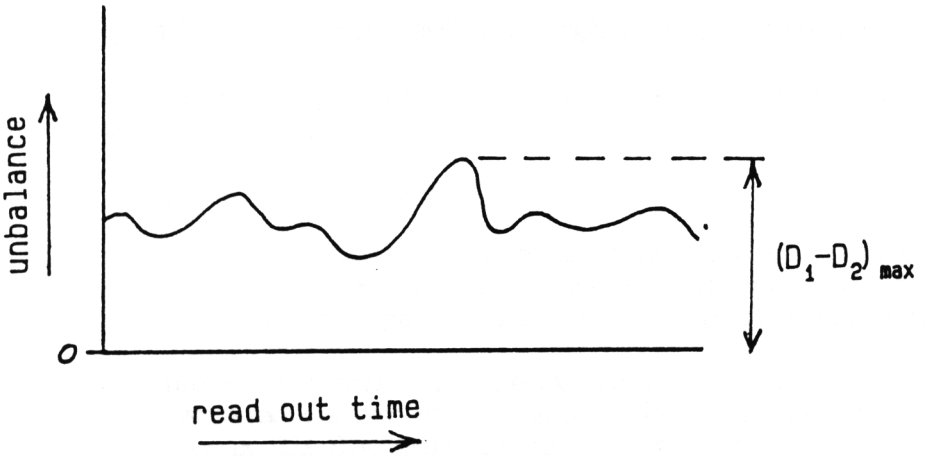


Fig A3.1: Unbalance versus read out time in a CD-MO system.

This unbalance can be caused by:

- Player electronics
- Player optics
- Disc:
  - substrate
  - recording

In order to investigate the unbalance caused by the substrate, the influence of player electronics, player optics and recording should first be eliminated. This can be done with means of an optimally recorded, glass CD-MO disc.
Then, the disc under investigation must be optimally recorded.
The resulting unbalance normalized to the sum signal D_1+D_2, called Optical Disc Unbalance or ODU, should now be smaller than 0.05.

A4. Measurement of the groove wobble amplitude.

The wobble amplitude in nm cannot easily be measured directly. However, it can be derived from the normalized wobble signal. The theoretical results for such a derivation are given below.

Relation between normalized wobble signal and wobble amplitude.

According to specification point 1.4.3, the wobble signal I_w can be seen as:

$$I_w = A * \sin(2*\pi*a/p) \qquad (1)$$

where a = wobble amplitude in nm (typical 30nm)
p = track pitch of the radial error signal
A = the peak value of the radial error signal

In figure A4.1 and A4.2 the parameters a, p, A and I_w are shown. The averaged center of the groove is taken as point 'o'. The groove has a peak displacement of 'a' (wobble amplitude) from the averaged center of the groove to the actual center of the groove. The normalized wobble signal can now be defined as:

$$\frac{I_{w\text{-}rms}}{(I_1-I_2)_{pp}} = \frac{I_w}{2*A*\sqrt{2}} = \frac{\sin(2*\pi*a/p)}{2*\sqrt{2}} \qquad (2)$$

where $I_{w\text{-}rms} = I_w / \sqrt{2}$ (3)

$(I_1-I_2)_{pp} = 2*A$ (4)

The definition in (2) is consistent with specification point 2.18.2. The wobble signal (1) is not only dependent on the wobble amplitude "a", but also the track pitch "p". Due to normalization, dependencies on groove geometry, spot shape and optical aberrations have been eliminated.

Tolerances of the normalized wobble signal.

From the above formula for the normalized wobble signal, the tolerances as given in specification point 2.18.2 can be converted to nm for a given track pitch of "p" = 1.6 microns.

Lower limit: 0.035 corresponds to 25 nm.
Upper limit: 0.050 corresponds to 36 nm.

Measurement suggestions.

The wobble signal and the push-pull signal should be filtered before measurement. The wobble signal should be filtered through a 10 - 30 kHz bandpass filter, the push-pull signal through a 5 kHz lowpass filter.
The wobble signal and the push-pull signal should be averaged over 10 seconds.

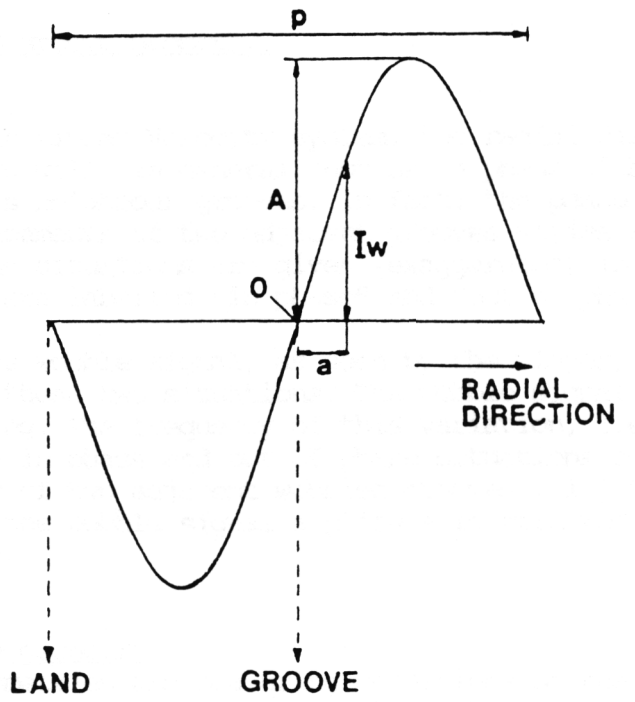


Fig A4.1 : the radial error signal

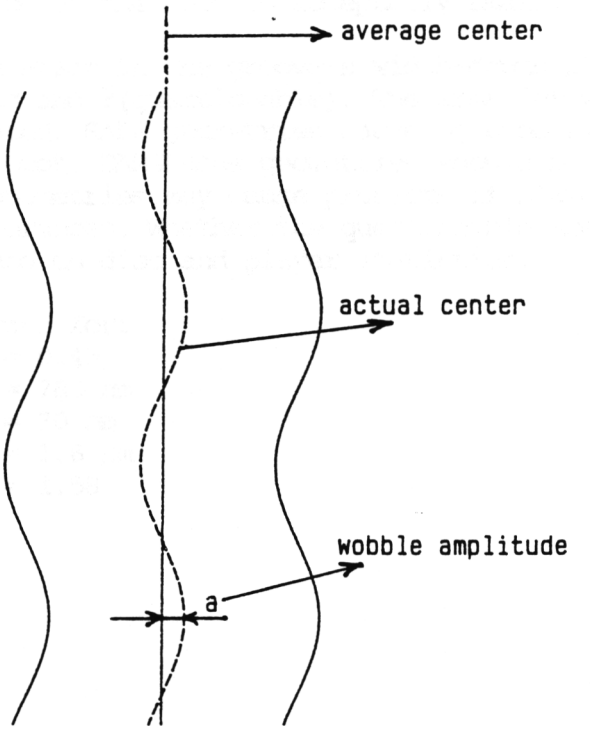


Fig A4.2: the groove wobble

A5. Beat of wobble and groove geometry.

Beat of the wobble.
Due to the Constant Linear Velocity system, the radial displacement of a wobbled groove will, in general, not be in phase with the displacement of its neighbour grooves. In fact, the phase difference between the displacements of two adjacent grooves varies along the groove. Two extreme situations are given (exaggerated) in figures A5.1 and A5.2 and are labelled "in phase" and "out of phase".

It appears that the wobble signal, as seen by the player, is more or less different in these two situations. The wobble signal amplitude is therefore varying. The frequency of this variation, i.e. the frequency at which in phase and out of phase situations occur, is the beat frequency of two adjacent wobbled grooves : 1 ± 0.4 Hz. This variation of the wobble signal amplitude is referred to as the beat of the wobble.

Defocus and groove geometry.
For the groove geometries and measuring conditions of the CD-MO system, the beat of the wobble has a typical value of $\pm 10\%$ in best focus. If the read-out spot is defocussed however, the beat may increase drastically. The wobble signal may then reach intolerably low values, resulting in a high ATIP Error Rate. The amount of beat increase depends on the groove geometry. It appears that wide and deep grooves are most sensitive to this phenomenon. Typical examples of measured ATIP and Block Error Rates on discs with wide grooves are shown in the figures A5.4 and A5.5. In figure A5.4 ATER is affected heavily, especially with a defocussed spot. In figure A5.5 the influence of the beat is acceptably small.

Figure A5.3 shows three areas in the groove's width-depth plane, labelled SAFE, DANGERous and ?(questionable). The area for wide CD-MO grooves is indicated. SAFE geometries cause no problems when read with a defocussed spot. DANGERous geometries should be avoided. Questionable geometries may cause problems if players and discs use all their tolerances. Whether the questionable area is usable or not will depend on disc and player statistics.

Note: Figure A5.3 is drawn for:

NA	= 0.45
Wavelength	= 780 nm
Wobble amplitude	= 30 nm
Track pitch	= 1.6 µm
Refractive index	= 1.58

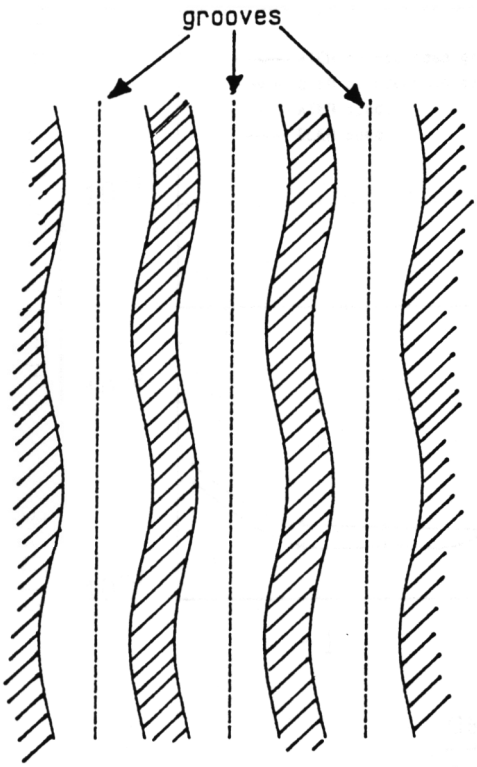


Fig A5.1: grooves "in phase"

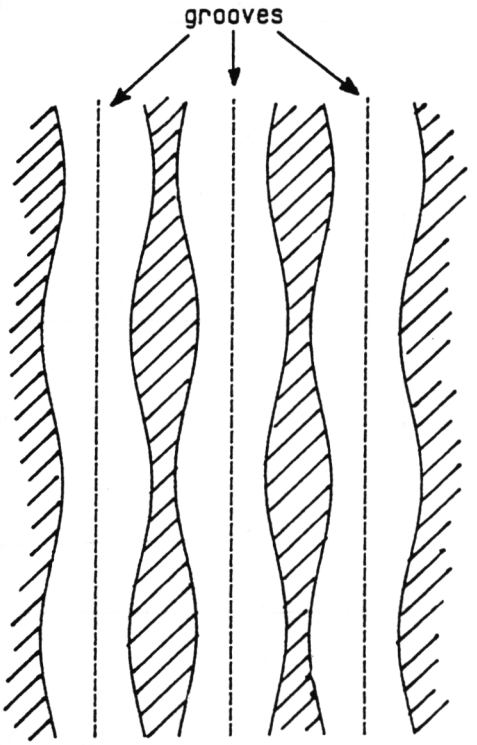


Fig A5.2: grooves "out of phase"

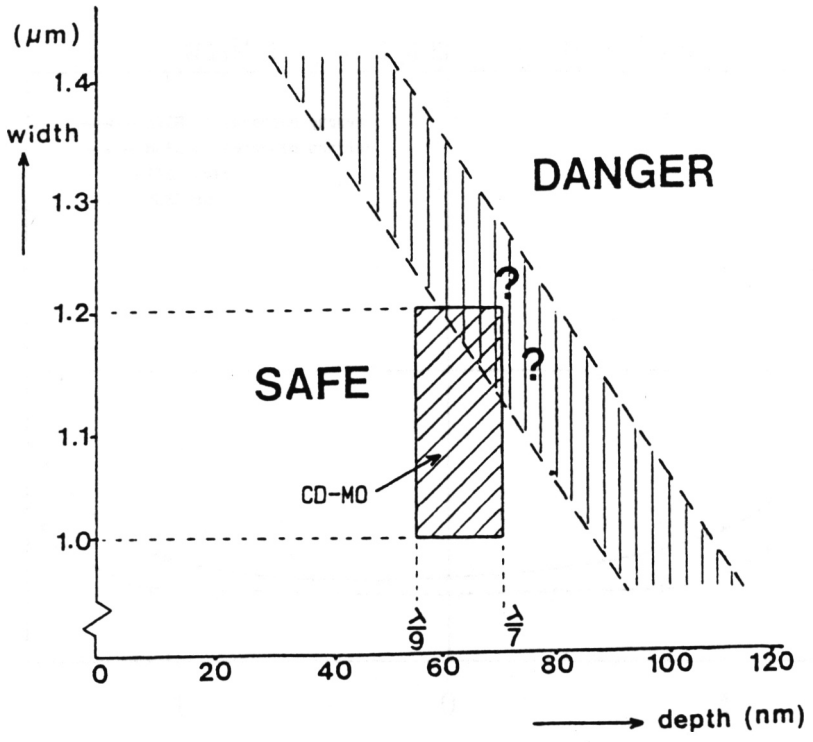


Fig A5.3: groove geometry

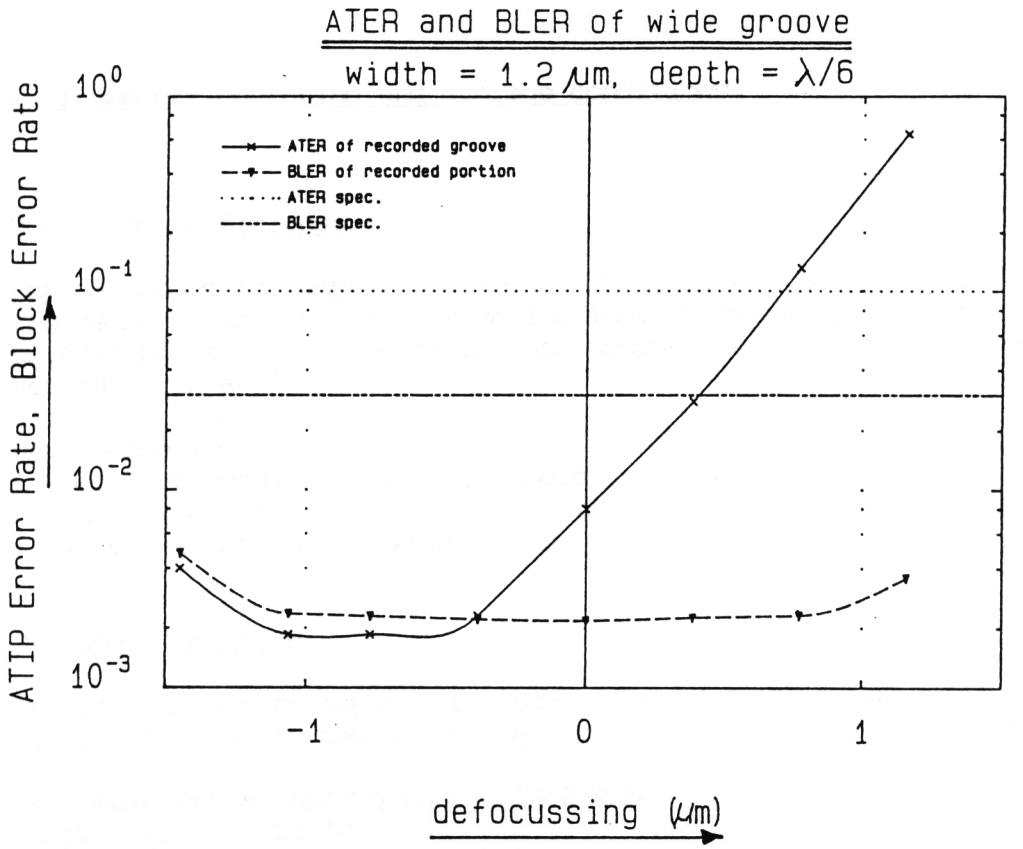


Fig A5.4: ATER and BLER windows for a defocussed system

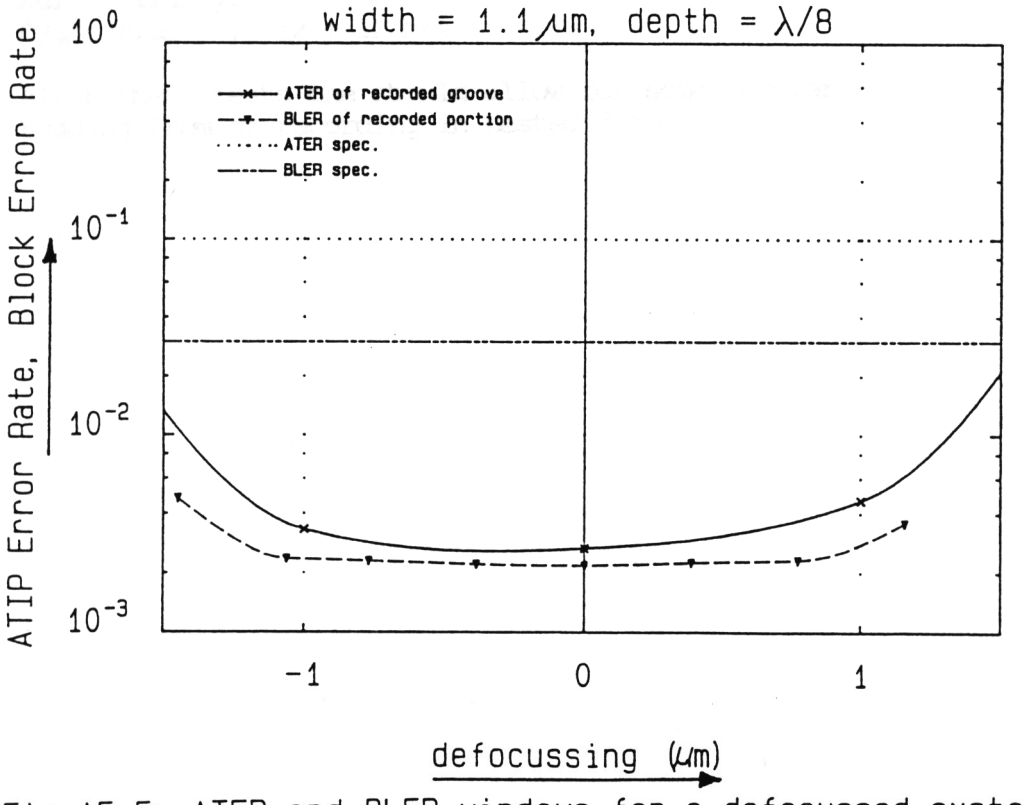


Fig A5.5: ATER and BLER windows for a defocussed system

A6. Environment: operating and storage conditions.

Operating Conditions:

Rapid changes in temperature and humidity within the specified ranges may cause too large a deflection. Recovery times up to several hours have to be taken into account before reading from or recording in a disc.

Recommendation:

* Before recording, the disc should be climatized to the players environment for at least 15 minutes.
* No condensation may occur on the disc.

Storage Conditions:

For storage and transport of discs before and after recording the following climatic tests are used to simulate typical conditions:

Dry Heat Test according to IEC 68-2-2 Ba

Temperature : 55 °C
Rel. Humidity: max. 50% at 35 °C
Storage Time : 96 hrs.

Cyclic Damp Heat Test according to IEC 68-2-30 Db

Temperature : 40 °C max.
Temperature : 25 °C min.
Cycles : 6
Rel. Humidity: 95%
Cycle Time : 12 + 12 hrs..

After these tests one should allow for some recovery time before reading from or recording in tested discs.

A7. Measurement of the optimum recording power P_0.

Disc manufacturers should determine the exact value for P_0 as follows:

1: A 720 kHz signal (continuous I_3 signal) is recorded on the disc with a recording power $P \geq 1.2 * P_0$ (P_0 is the estimated optimum recording power) and a magnetic field H_{ext}=400 Oe.

2: EFM data signals should be recorded over the already recorded 720 kHz signal of step 1. The magnetic field H_{ext}=200 Oe. Different recording powers should be used, in order to obtain a curve like in Figure A7.1.

3: After BLER values of the recorded EFM have been measured (see Figure A7.1), the optimum recording power P_0 can be calculated from:

$$P_0 = \frac{P_{min} + P_{max}}{2}$$

4: If the value for P_0, calculated in step 3, is higher than $1.4 * P_{min}$, then $P_0 = 1.4 * P_{min}$ should be taken as the optimum recording power P_0.

Whether a disc fullfils requirement 2.14.5 (For $P_0 \pm 0.2 * P_0$, the disc must be recordable within spec for $100 < H_{ext} < 400$ Oe) must be determined as follows:

5: See step 1.

6: EFM data signals should be recorded over the already recorded 720 kHz signal of step 5. The magnetic field H_{ext}=100 Oe. Different recording powers should be used, in order to obtain a curve like in Figure A7.1.

7: EFM data signals should be recorded over the already recorded 720 kHz signal of step 5. The magnetic field H_{ext}=400 Oe. Different recording powers should be used, in order to obtain a curve like in Figure A7.1.

8: For the curves of both step 6 and 7 should fullfil the requirements: $P_{min} \leq 0.8 * P_0$ and $P_{max} \geq 1.2 * P_0$, where P_0 is the optimum recording power as determined in step 1 to 4.

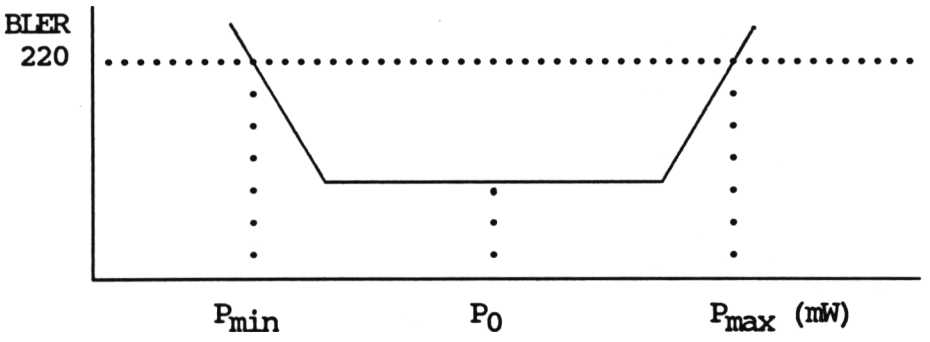


Figure A7.1: Recording power (mW) versus BLock Error Rate (sec^{-1}).

A8. Measurement of Jitter and Single Frequency Time Errors.

A8.1 Definitions:

Land jitter:
Land jitter is detected from the I_3 component of the unequalized HF signal and is the 1 sigma value of the time length and position variations measured from the rising edge to the falling edge of the unrecorded I_3 effect between consecutive pits.

Pit jitter:
Pit jitter is detected from the I_3 component of the unequalized HF signal and is the 1 sigma value of the time length and position variations measured from the falling edge to the rising edge of the recorded I_3 effect between consecutive lands.

A8.2 Measurement of jitter.

Measurement apparatus:
Use can be made of commercially available CD jitter meters or time interval analyzers for the measurement of jitter. The jitter meter or analyzer should include the following:

* A data slicer or adaptive level detector.
* Polarity switch (for land and pit jitter).

A8.3 Single Frequency Time Errors.

It is impossible to characterize all single frequency time errors which may occur on each disc. Therefore is specified that the maximum value in μs of any single frequency time error should be below the value given in Figure 2.2 of the Orange Book Part I. An example (which is common to both disc and player) is eccentricity. In practice this is often the main source of single frequency time errors originating from the disc.

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Confidential Information



Recordable Compact Disc Systems

Part II : CD-WO

System Description
November 1990

Sony Corp.

N.V. Philips

- C O N T E N T S P A R T II -

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1. General

1.1. Scope

The CD Write Once (CD-WO) system gives the opportunity to write once and read many times CD information. The recorded CD-WO disc is Red Book compatible, so it can be played back on conventional CD-players. The CD-WO format gives the possibility for both Audio and Data recording.

1.2. General Description

In the CD-WO system the disc contains a recording material which has a reflection decrease due to recording. After recording, the CD-WO disc satisfies the specifications as written in the chapter DISC SPECIFICATION of the Red Book.
The Information Area of a blank CD-WO disc has a wobbled pre-groove for tracking, CLV speed and timing purposes.
Recording takes place in the groove.

Remark 1: All parameters mentioned in this Orange Book Part Two refer to the 12 cm disc only. For the 8 cm disc these parameters (e.g. diameters) should be corrected according to the parameters given in the Red Book on page 84 up to 86 (description of 8 cm CD-single).

Remark 2: When the chapter DISC SPECIFICATION of the Red Book is being referred to, the pages 74 up to 83 are excluded (description of CD-Video).

Remark 3: Apart from the disc described above, another disc concept may be used, in which the disc contains both an area with pre-mastered or pre-recorded information and a recordable area. This is called the hybrid disc, see chapter 11.

Remark 4: For Data applications, the term 'Red Book' in this Orange Book Part II should be replaced by 'Yellow Book' or 'Green Book' if necessary for recording Data instead of Audio information.

1.3. References

Red Book : Compact Disc Digital Audio System Description,
N.V. Philips and Sony Corporation.

Yellow Book : Compact Disc Read Only Memory System Description,
N.V. Philips and Sony Corporation.

Green Book : Compact Disc Interactive Media full functional specification,
N.V. Philips and Sony Corporation.

1.4. Definitions

1.4.1. General

- CLV : Constant Linear Velocity.

- Groove: The guidance track in which identical clocking and time code information is seen at both edges.

- Land : The area between the grooves.
  Note: In HF measurements (e.g. jitter) 'Land' is often used as the area between pits.

- Pit : Recorded effect ($I_3..I_{11}$ effects)

- Wobble: The pregroove in the disc is not a perfect spiral but is wobbled with:
  - a typical amplitude of 30 nm
  - a spatial period of 54 to 64 µm
  When the wobble is locked to a frequency of 22.05 kHz, the velocity of the disc should have a specific value in the range of 1.2 to 1.4 m/s.

- ATIP : Absolute Time In Pregroove. With an additional modulation of the groove wobble, the pregroove contains a time code information called ATIP (see chapter 4).

- ATER : ATIP Error Rate. Number of erroneous ATIP frames in proportion to the total number of frames.

- P_0 : The optimum recording power, as determined by OPC.

- OPC : Optimum Power Control: See Attachment B3.

- Laser Modulation: During recording, the laser is switched on and off according to the 'Write Strategy'.

- Write Strategy: The exact description of the 'Laser Modulation'. The Write Strategy which should be used for recordings which are necessary for disc measurements is described in chapter 2. : The 'Recorder optical pick up'.

- Laser peak power: The (averaged) top level of the laser power at the disc surface when recording an $I_3..I_{11}$ effect.

- CW : Continuous Wave. The laser light output is at a constant level.

- PMA : Program Memory Area: See chapter 1.4.2.

- PCA : Power Calibration Area: See chapter 1.4.2.

- Block : A unity of 2352 bytes as defined in the Yellow Book (page 100).

- Jitter: The 1 σ value of the time variations between consecutive I_3 transitions (a transition from pit to land and vice versa) of the unequalized HF signal (random EFM data). For the measurement of jitter, see Attachment B9.

- Normalized Push pull Ratio (NPPR): The resulting value, when the normalized push pull amplitude before recording is divided by the normalized push pull amplitude after recording. See also chapter 1.4.3: Signals after rec.
  - Push pull amplitude before recording is normalized to the groove level I_g before recording.
  - Push pull amplitude after recording is normalized to the averaged groove level I_{ga} (see chapter 1.4.3) after recording.

- Pre-recorded Information: Information, already present before the disc is obtained. It is stored on the disc by recording it after the disc is manufactured.

- Pre-mastered information: Information, already present before the disc is obtained. It is stored on the disc during the manufacturing process of the disc (when making the 'master').

- Reserved : e.g. 'Reserved and set to zero' means: until further notice the value should be zero. In future, the use of other values might be specified.

1.4.2. Disc areas:

In order to describe all disc areas, we define three recording states of a CD-WO disc:

The layout of the Unrecorded disc is given in Figure 1.1.
The layout of the Partially Recorded disc is given in Fig. 1.2.
The layout of the Recorded disc is given in Figure 1.3.

Remarks:
* Only the Recorded disc can be played back on a conventional CD player.
* For further descriptions of each disc area, see chapter 5.

The Unrecorded, blank disc:

Information Area: The Information Area of an unrecorded CD-WO disc contains a pregroove with CLV clocking information and a time code.
The start time is 35 seconds 65 frames (00:35:65 ATIP) before the start of the Lead In Area. This corresponds to a starting diameter of 44.7 +0.3/-0.0 mm. The maximum outer diameter is 118 mm (or 77 mm for the 8 cm CD-single).

The Partially Recorded disc:

The CD-WO system gives the opportunity to record a disc in several interrupted recording actions (e.g. at a different time, on a different recorder).
With respect to Data Organization (See chapter 5) the Information Area is divided into five parts.

1: Power Calibration Area (partially recorded)
2: Program Memory Area (partially recorded)
3: Lead In Area (unrecorded)
4: Program Area (recorded)
5: Recordable User Area + Lead Out Area (unrecorded)

1: Power Calibration Area:
The Power Calibration Area (PCA) can be used for e.g. Optimum Power Control procedure (see Attachment B3) before the actual recording of the information.
It starts 35 seconds 65 frames (00:35:65 ATIP) before the start of the Lead In Area (encoded in ATIP).
It ends at the start of the Program Memory Area, which is 13 seconds 25 frames (00:13:25 ATIP) before the start of the Lead In Area.

2: Program Memory Area:
After an interrupted recording action, the track information of the already recorded tracks is stored in the Program Memory Area (PMA). After recording of the last track, the complete track information will be stored in the TOC. The PMA starts 13 seconds 25 frames (00:13:25 ATIP) before the start of the Lead In Area. It ends at the start of the Lead In Area (encoded in ATIP).

3: Lead in Area:
The Lead in Area is reserved for the recording of the Table Of Contents (TOC) according to the specifications in chapter 5.5.
The starting diameter is 46 +0.0/-0.2 mm. The start time is encoded in ATIP. It ends at the start of the Program Area (50 +0.0/-0.4 mm).

4: Program Area:
In the Program Area the Tracks with user information have been recorded. The tracks can be both Audio and Data Tracks.
The starting diameter is 50 +0.0/-0.4 mm and the maximum outer diameter is 116 mm (according to Red Book specification).

5: Recordable User Area + Lead out Area:
This area is reserved for the recording of additional tracks with user information, and the Lead Out according to the specifications in the Red Book. This area starts right after the Program Area. When finalizing the disc, the Lead-Out is recorded right after the last recorded track. The Lead-Out is at least 1.0 mm in diameter wide and it ends maximally at 118 mm (according to Red Book spec.).

The Recorded disc:

After finalizing the recording, the CD-WO disc is compatible with the Red Book definitions and specifications, and can therefore be played back on any conventional CD player.
The Information Area of the Recorded disc consists of three parts:

1: The Lead in Area (See Red Book and chapter 5.5)
2: The Program Area (See Red Book)
3: The Lead out Area (See Red Book)

1.4.3. Signals:

Signals before recording:

I_0 : Blank area level

I_1 : Land level

I_g : Groove level before recording

$RC_b = 2(I_1-I_g)/(I_1+I_g)$: Radial Contrast before recording

$|I_1-I_2|/I_g$ at 0.1 μm radial offset : Push Pull amplitude before recording.
* (I_1-I_2) is measured after low-pass filtering (f < 5 kHz).
* for explanation, see Attachment B6 and the Red Book Chapter 15.1

$I_w=(I_1-I_2)$: Wobble signal
* (I_1-I_2) is measured after band-pass filtering (10 < f < 30 kHz).

$I_{w(rms)}/|I_1-I_2|_{(pp)}$: Normalized wobble signal
* see Attachment B7.

Signals after recording :

I_{top} : Top level of recorded I_{11} signal
* see Red Book Chapter 14

I_{ga} : Averaged groove level after recording.
* I_{ga} is defined as the averaged HF signal (τ=15 μs), measured in the groove, before AC coupling.

$RC_a=2(I_1-I_{ga})/(I_1+I_{ga})$: Radial Contrast after recording.

I_3/I_{top} : Modulation amplitude of I_3 signal
* see Red Book Chapter 14

I_{11}/I_{top} : Modulation amplitude of I_{11} signal
* see Red Book Chapter 14

$|I_1-I_2|/I_{top}$ at 0.1 μm radial offset : Push Pull amplitude after recording.
* (I_1-I_2) is measured after low-pass filtering (f < 5 kHz)
* for explanation, see Attachment B6 and the Red Book Chapter 15.1

$R_{top}=R_0*I_{top}/I_0$: Reflectivity of the recorded disc relative to I_{top}.
* R_0 is the reflectivity of a blank area of the disc.
* see Attachment B2 and B8.

$$\frac{|I_1-I_2|/I_g}{|I_1-I_2|/I_{ga}}$$

: Normalized Push Pull Ratio (NPPR)
* $|I_1-I_2|/I_g$ is measured before recording.
* $|I_1-I_2|/I_{ga}$ is measured after recording.
* See chapter 1.4.1 and Attachment B6.

2. Disc specification

For a good comparison between different measurements, we define the atmospheric conditions and the optical pick up unit which should be used for measurement of all characteristics specified in this chapter 2.

Standard atmospheric conditions for testing.
Measurements and mechanical checks are to be carried out at any combination of temperature, humidity and air pressure within the following limits, unless otherwise specified:

Ambient temperature	:	15°C to 35°C
Relative humidity	:	45% to 75%
Air pressure	:	86 kPa to 106 kPa.

The optical pick up unit for disc measurements.
All signal measurements are done without read equalization. In practical players and recorders we recommend however to use read equalization in order to improve margins.
We define two different optical pick up units for measurements:

* The 'Read Only optical pick up' should be used for measurements of the characteristics in chapter 2.2: 'The recorded disc.' The specification of this pick up unit is equal to the specification of the pick up in the Red Book on page 2:

Wavelength	:	780 ± 10 nm
NA	:	0.45 ± 0.01
Polarization	:	circular
Wavefront distortion	:	< 0.05 λ (RMS value)
Rim intensities:		
Tangential	:	> 0.5
Radial	:	> 0.5
Laser read power	:	< 0.7 mW, CW in the central spot.

* The 'Recorder optical pick up' should be used for measurements of the characteristics in chapter 2.1: 'The unrecorded disc', and for the recordings which are necessary for disc measurements. The specification of this pick up unit is:

Wavelength	:	780 - 790 nm
NA	:	0.50 ± 0.01
Polarization	:	circular
Wavefront distortion	:	< 0.05 λ (RMS value)
Rim intensities:		
Tangential	:	0.5 - 0.6
Radial	:	0.25 - 0.5
Laser power:		
Reading	:	< 0.7 mW, CW in the central spot.
Recording	:	according to 'Write strategy'.

Write Strategy:
The laser power during recording is modulated according to the (n-1) strategy, with an additional energy of 10% for the I_3 pulse. This additional energy should be applied by adding 50 ns pulse duration to the end of the I_3 pulse. The (n-1) strategy means that the length of a laser write pulse for an effect I_n is (n-1)*T, where:
* T = length of one clock cycle: 231.4 ns
* n = 3..11 : the number of clock cycles in an effect I_n.

Characteristic to be specified	Requirements	Remarks

2.1. The unrecorded disc.

- The unrecorded CD-WO disc fulfills the requirements as written in the chapter DISC SPECIFICATION of the Red Book, except for the items mentioned in this chapter 2.1.
- The paragraphs mentioned in this chapter 2.1 replace the paragraphs with the same numbering of the Red Book.

	Characteristic to be specified	Requirements	Remarks
	Outer diameter:		
2.5	Disc unbalance	< 0.04 N	measured at 10 revolutions/sec
	Optical requirements:		
8.6	Optical quality of the disc:	wave front distortion < 0.05 λ (RMS value)	
9.	Information Area		
9.1	Start time:	Start time is 35 sec and 65 frames (ATIP) before the start time of the Lead In Area.	Corresponding start diameter 44.7 $^{+0.3}_{-0.0}$ mm.
9.2	Max. outer diameter:	118 mm	
14.	Sensitive layer		In the Information Area
14.1	Polarity of modulation:	High to Low	
14.2	CNR for periodic effects in the range from 200-720 kHz:	≥ 47 dB	BW=10kHz
15.	Radial tracking signals		
15.1	Normalized Push pull Ratio	0.5 - 1.0	See chapters 1.4.1 and 1.4.3 and Attachm. B6
15.2	Max. variation of Push pull amplitude	± 15 %	On one disc

Characteristic to be specified	Requirements	Remarks
15.3 Radial noise:	See Red Book: 15.2	
15.4 Radial Contrast:	$RC_b > + 0.05$	
16. Tangential tracking signals		
16.1 Locking frequency for the groove wobble	22.05 kHz	
16.2 Normalized wobble signal	0.035 - 0.050	See Attachm. B7
16.3 CNR of Wobble	> 35 dB	BW=1kHz
17. Time encoding		
17.1 Wobble modulation:	ATIP	
17.2 ATER:	< 10 %	averaged over any 10 seconds
17.3 Max. number of successive erroneous ATIP frames:	3 frames	
18. Write conditions		
18.1 General Recording Strategy:	- In groove - Laser Modulation	
18.2 Optimum recording power of a disc:	P_0 determined by OPC	β=0.04 criterion see Attachm.B3. Indicative value for P_0 in ATIP, see chapt.4.4
18.3 Optimum recording power range for all discs:	$4 \leq P_0 \leq 8$ mW	Peak power in central spot, T=25°C, NA=0.50
18.4 Recording power window of a disc:	For $P_0 \pm 0.15*P_0$, disc must be recordable within specifications	For T=25°C
18.5 Maximum variation of P_0 on one disc:	$\pm 0.05*P_0$	
18.6 Wavelength of recording spot:	$775 < \lambda < 800$ nm	See Chapter 3

Characteristic to be specified	Requirements	Remarks
19. Local defects	See Red Book: 15.3 and Attachment 7	
20. Environment (operating conditions during recording)	Disc must be recordable in all combinations given in Figure 2.1.	See Attachm.B4
20.1 Temperature range	T = -5 to +55°C	
20.2 Absolute humidity	0.5 to 30 g/m^3	
20.3 Relative humidity	5% to 95%	

2.2. The recorded disc

- The recorded CD-WO disc fulfills all requirements as written in the chapter DISC SPECIFICATION of the Red Book.
- In addition, the recorded disc has to fulfill the requirements as described in this chapter 2.2.
- The paragraphs marked with the prefix **ad** (e.g. ad 8.4.) are **additions** to already existing paragraphs in the Red Book.

Characteristic to be specified		Requirements	Remarks
ad 8.4.	Reflection and double pass substrate transmission (see Red Book 8.4):	$R_{top} > 0.65$	(see attachment B2).
ad 14.	HF signal:		
14.5	Jitter:	< 30 ns	See chapter 1.4.1 and Attachment B9.
14.6	Single frequency time errors:	The spectral components of the time errors should be below the values given in fig 2.2	For spectral components $f \leq 4$ kHz; see Attachment B9.
ad 15.	Radial tracking signals:		
ad 15.1	Push pull amplitude	0.04 - 0.07	See Attachm.B6
15.4	Radial Contrast	$RC_a > 0.2$	
17.	Tangential tracking signals:		
17.1	Locking frequency for the groove wobble	22.05 kHz	
17.2	CNR of Wobble	> 20 dB	BW=1 kHz
18.	Read conditions		
18.1	Power of read spot	≤ 0.7 mW	CW, in the central spot
18.2	Read stability	$>10^6$ times successively read from a single track, the disc should remain within spec.	For T=70°C and P_{read}=0.7 mW
18.3	Wavelength of read spot	$770 < \lambda < 830$ nm	Red Book p 12

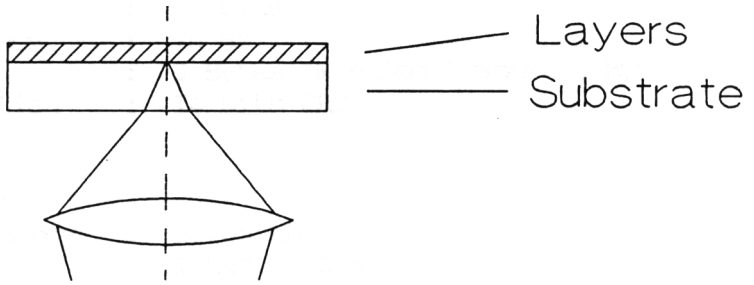
3. Optical stylus

The optical stylus of any CD-WO recorder has to fullfil the following requirements:

* The system is optimized for wavelengths between 775 and 800 nm.
* The wavelength λ and the numerical aperture NA have to fulfill the requirement:

$$\lambda / NA \leq 1.6\ \mu m$$

* The optics of the stylus should be diffraction limited.
* The information is viewed through a transparent, plane parallel plate of 1.2 mm thickness, with a refractive index of about 1.55.
* The depth of focus of the optical stylus is approximately 1.6 μm.



For further description of the optical principles of the CD-WO system, see Attachment B1.

4. Pregroove modulation, ATIP

By means of ATIP (Absolute Time In Pre-groove) the CD-WO disc contains motor control information (the carrier frequency) and time-code information (modulation of the carrier frequency). The ATIP time-code increases monotonically throughout the disc.

4.1. General parameters

Disc	:	Radial track-wobble
Analog modulation	:	FM
Carrier frequency	:	22.05 kHz
Digital modulation	:	Biphase-Mark
Synchronization	:	Biphase violation
Data bit-rate	:	3150 Bits/Sec
Frame length	:	42 bits
Frame frequency	:	75 Hz
Data contents	:	3 Bytes (Min Sec Frames, 1 Byte each)
Error protection	:	14 bits CRC

4.2. FM modulation

Carrier frequency	:	22.05 kHz
Deviation	:	1 kHz $\pm$ 10 %
Oscillator output	:	Sinewave
Oscillator THD	:	< - 40 dB

4.3. Frame format

The format of one ATIP frame is :

Nr of Bits	4	8	8	8	14
Bit position	1234	111 56789012	11111112 34567890	22222222 12345678	23333333333444 90123456789012
Data	Sync	Minutes	Seconds	Frames	CRC remainder

4.3.1. Frame synchronization

For synchronization of the ATIP data the Biphase-Mark code rules are violated. The synchronization pattern used is 11101000 if the preceding cell = 0, or 00010111 if the preceding cell = 1.

Example-1 :

Wave form



Channel-bits	0	1 1 1 0 1 0 0 0	1 1	0 1	0 1	0 1	0 0	1 1	0 1	0
Data bits		< SYNC >	0	1	1	1	0	0	1	

Example-2 :

Wave form 

Channel-bits

	1	0	0	0	1	0	1	1	1	0	0	1	0	1	0	1	0	1	1	0	0	1	0	1
Data bits		<			SYNC				>	0		1		1		1		0		0		1	

4.4. Data format

The format of the ATIP time information is identical to the time encoding in Subcode-Q and in the CD-ROM header. The ATIP time information is represented in Binary Coded Decimal (BCD) with the most significant bit first as follows :

Minutes : 2 digits BCD, MSBit on position 5
Seconds : 2 digits BCD, MSBit on position 13
Frames : 2 digits BCD, MSBit on position 21

In addition to the normal time code, special CD-WO information is encoded in the ATIP time code.
The special information is identified by combinations of the MSB's of the Minutes, Seconds and Frames bytes (bit 5, 13 and 21).
The sequence of successive ATIP frames should be (see Fig. 4.1):

* One ATIP frame encoded with special information, followed by nine ATIP frames encoded with normal time information.
* This sequence should be successively repeated.
* The three specially encoded frames should be used cyclic.

bit 5	13	21	
0*******	0*******	0*******	: time in Program Area
0*******	0*******	1*******	: reserved
0*******	1*******	0*******	: reserved
0*******	1*******	1*******	: reserved
1*******	0*******	0*******	: time in Lead in
1*******	0*******	1*******	: recording power/Disc Application* **
1*******	1*******	0*******	: start time of Lead in*
1*******	1*******	1*******	: last possible start time of Lead out*

Example-1:
Last possible start time of Lead out: 70 45 15
11110000 11000101 10010101

Example-2:
Start time Lead in: 97 41 00
10010111 11000001 00000000

See also Figure 4.2

* : 1 out of 30 ATIP frames in Lead in Area. As there are three specially encoded frames, 1 out of 10 ATIP frames will contain special information.

** : Recording power/Disc Application:

In the Minutes, Seconds and Frames bytes with a MSB combination 101 (bit 5, 13, 21), there are two special encodings:

1: A value for the recommended optimum recording power of the disc. This value is given for a laser wavelength of 785 nm and T = 25 °C. The optimum recording power P_0 may depend on the wavelength. Each individual recorder might have a different laser wavelength. Therefore this encoded value can only be used as a first estimation of the exact value of P_0. It can be used as a reference value P_{ref} for an accurate determination of P_0 in an Optimum Power Control procedure, as described in Attachment B3.

2: Disc Application Code:
This code distinguishes between discs used for different applications. The two main application categories are: 'Discs for unrestricted use', and 'Discs for restricted use'. Within the category 'Discs for restricted use', an additional encoding may be used for the identification of Special Disc Applications.

	MSB							LSB
Minutes:	5	6	7	8	9	10	11	12

bit 5 = 1 : Lead in Area
bit 6..bit 8 : Optimum recording power in mW for λ = 785 nm and T = 25 °C.
= 000 : 4.0 mW
= 001 : 4.4
= 010 : 4.9
= 011 : 5.4
= 100 : 5.9
= 101 : 6.6
= 110 : 7.2
= 111 : 8.0

bit 9..bit 12 = 0000 : reserved

Seconds:

bit 13 = 0

bit 14..bit 20 : Disc Application Code.

bit 14 = 0 : Disc for restricted use.
bit 15..20 = 000000: General Purpose disc.
bit 15..20 = others: Special Purpose disc. Reserved for the encoding of Special Disc Applications.

bit 14 = 1 : Disc for unrestricted use.
bit 15..20 = 000000 : reserved.

Frames:

bit 21 = 1
bit 22..bit 28 = 0000000: reserved

4.5. Error detection

The error detection method uses a 14 bits CRC on Minutes, Seconds and Frames. The CRC codeword must be divisible by the check polynomial. The most significant bit of the CRC codeword is bit 5, the least significant bit is bit 42 of the ATIP frame. The CRC parity bits (bit 29 .. 42) are inverted on the disc.

The check polynomial is :

$$P(X) = X^{14} + X^{12} + X^{10} + X^7 + X^4 + X^2 + 1$$

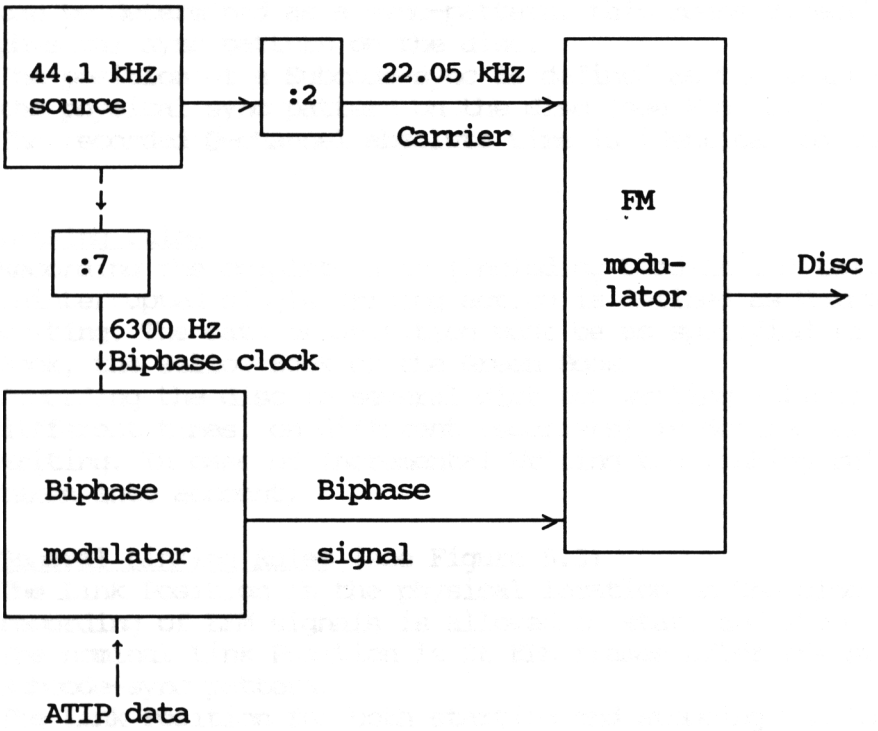
4.6. Bit rate

Bit rate = nr of addresses/sec * nr of bits/address
= 75 * 42
= 3150 bits/sec.

The bit rate is 1/7 of the 22.05 kHz wobble frequency. Both the 22.05 KHz wobble and 6.3 KHz biphase clock frequencies are derived from the same 44.1 kHz source.

4.7. ATIP encoder

The block diagram of the ATIP encoder is :



5. Data organization

- The encoding rules for CD-Audio Tracks are as given in the Red Book unless specified otherwise in this document.
- The encoding rules for Data Tracks are as given in the Yellow Book or the Green Book unless specified otherwise in this document. As this chapter 5 is basically written as an extension to the Red Book, some specification items must be replaced by the items in the Yellow Book or Green Book, if recordings according to these books are made.
- The Information Area of a CD-WO disc is divided into the following area's (see chapter 1.4.2 and the Figures 1.1, 1.2, 1.3, and 5.1):

1: Power Calibration Area
2: Program Memory Area
3: Lead-In Area
4: Program Area
5: Recordable User Area + Lead-Out Area

5.1. ATIP synchronization rule

On the whole disc the allowed tolerance between the position of the ATIP sync and the Subcode sync is $\pm$ 2 EFM frames.
The position of a ATIP-sync is defined as the position where a sync can be determined as a sync-pattern; this means directly after the physical sync pattern on the disc.
The position of a Subcode-sync is defined as the start-position of the physical sync pattern on the disc (see Fig. 5.2).
The recorded Q-channel absolute time is identical to the ATIP time.

5.2. Linking rules

Recording the complete disc (including Lead-In and Lead-out) in an uninterrupted single writing action is defined as **Uninterrupted Writing**. The data organization must be as specified in the Red Book, the Yellow Book or the Green Book.
Recording the disc in several distinct writing actions (e.g. at different times, on different recorders) is defined as **Incremental Writing**. In case of Incremental Writing the linking rules must be taken into account.

5.2.1 General Linking Rules (see Figure 5.3)

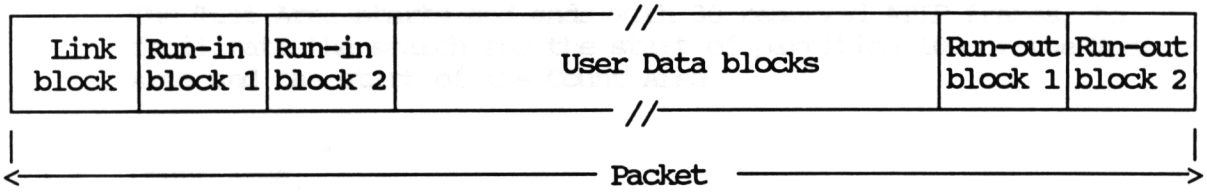
The Link Position is the physical location on the disc where the recording of EFM signals is allowed to start and stop.
The nominal Link Position is 26 EFM frames after the start of a Subcode-sync pattern.
The Link Position for both starting and stopping has to be 26 +1/-1 EFM frames after the start of the Subcode-sync.
As a result, in case of Incremental Writing, a gap or an overwriting of maximum 2 EFM frames can occur and is allowed.
In the Information Area the start of EFM recording must be at a Link-position.

5.2.2 Audio Linking

At least 1 interleave length of digital silence is recommended at the beginning and at the end of a sequence of EFM recording (audio applications only).

5.2.3 Data Linking

The start of a Block sync (before CIRC/EFM encoding) is within +36 and -10 EFM frames after the start of a subcode sync.
At the start of an EFM recording in a Data track, one Link block and two Run-in blocks must be recorded. At the end of an EFM recording in a Data track, two Run-out blocks must be recorded.



One set of recorded Link-, Run-in, User Data- and Run-out blocks is called a Packet.
The number of User Data blocks in a Packet is called the Packet Size.
Identification of the Link-, Run-in, User Data- and Run-out blocks is in the Mode byte (in the Block Header, see Yellow Book page 101). The lay-out of this Mode byte is (bit 7 is first bit and MSB):

bit 7..5 : Block indicators
= 000 : Data block
= 110 : First Run-out block
= 111 : Second Run-out block
= 011 : Link block: physical linking of EFM data according to the General Linking Rules in chapter 5.2.1
= 010 : First Run-in block
= 001 : Second Run-in block
= 100 : reserved
= 101 : reserved

bit 4..2 = 000 : reserved

bit 1..0 : Yellow Book Mode indication
= 00 : mode-0
= 01 : mode-1
= 10 : mode-2
= 11 : reserved

5.3. Power Calibration Area

The Power Calibration Area (PCA) is reserved for obtaining the correct recording power for a disc. The PCA is divided in two area's (see Fig. 5.1):
1: The Test Area, in which tests can be performed to obtain the correct recording power for a disc.
2: The Count Area, where can be read which partition of the Test Area can be used.

5.3.1 Test Area.

The Test Area is reserved for performing OPC procedure as described in Attachment B3.
The start time is 00:35:65 ATIP before the start of the Lead In Area. It ends 00:15:05 before the start of the Lead In Area, which is the start of the Count Area. The start of the Lead In Area is encoded in ATIP during the Lead In Area (see Chapter 4.4).
The Test Area is divided in 100 numbered partitions. Partition

numbering increases from 1 to 100 from outside to inside disc diameter (backwards numbering from the end of the Test Area to the start, see Fig. 5.1).
Each partition is 15 ATIP frames long (15/75 seconds).
Each partition number p starts at a fixed ATIP time, and ends at the start of partition (p-1). Partition p starts (p*15 + 1160) ATIP frames before the start of the Lead In Area (see Fig. 5.1).
The Test Area starts and ends with 30 reserved ATIP frames, to facilitate the search for the start of partition 100 of the Test Area and the start of the Count Area.

5.3.2 Count Area.

The Count Area provides a reliable and fast detection of the first usable, free partition in the Test Area.
The Count Area starts 00:15:05 ATIP before the start of the Lead In Area, which is the end of the Test Area. It ends 00:13:25 ATIP before the start of the Lead In Area, which is the start of the Program Memory Area (see Fig. 5.1).
The Count Area is divided in 100 numbered partitions. Partition numbering increases from 1 to 100 from outside to inside disc diameter. Each partition in the Count Area is 1 ATIP frame long (1/75 seconds). Each partition p starts at a fixed ATIP time and ends at the start of partition number (p-1). Partition p starts (p*1 + 1030) ATIP frames before the start of the Lead In Area (see Fig. 5.1).
The Count Area ends with 30 reserved ATIP frames, to facilitate the search for the start of the Program Memory Area.
Partition p in the Count Area should be recorded with EFM, after partition p in the Test Area has been used for performing an OPC procedure.
By counting the number of empty partitions E in the Count Area (from the start up to the first recorded partition), the first usable partition U in the Test Area is determined by U=101 - E.
In the Count Area EFM recording should be as specified for the rest of the Information Area. The Linking Rules however are allowed to be violated.

5.4. Program Memory Area

The Program Memory Area (PMA) starts at 00:13:25 ATIP before the start of the Lead In Area. It ends at the start time of the Lead In Area, which is encoded in ATIP during the Lead In Area (see chapter 4.4).
The PMA contains information about the Partially recorded disc. This information is encoded in the subcode Q-channel.

5.4.1. Contents.

The PMA may contain three types of information:

1: Track numbers with their start and stop time. This is the table of contents for the partially recorded disc.
2: Disc identification (optional). A six digit number can be recorded in the disc to identify each disc.
3: Skip/Unskip information (optional). It is possible to indicate that an entire track or a part of a recorded track (a time interval) should be skipped during play back of the disc. Unskip means that this instruction to skip is cancelled.

5.4.2. Recording sequence.

An uninterrupted recording action in the PMA should always be performed in a multiple of ten subcode frames. Within such unity of ten frames, the successive frames are labelled 0 (first frame) to 9 (last frame) in the ZERO byte of the subcode-Q channel. In the recorded part of the PMA, this ZERO byte should continuously repeat this cyclic counting from 0 to 9.
The specific contents, the information within a subcode frame, is called an Item. An Item is repeated five times in five successive subcode frames. As a unity consists of ten subcode frames, these five successive repetitions of an Item are labelled 0 to 4 or 5 to 9. When an uneven number of Items should be recorded, the last of these Items is repeated ten times in stead of the usual five times, because recording should be always in multiples of ten subcode frames. In this case, the ten successive repetitions are labelled 0 to 9 in the ZERO byte.
The first Item is recorded at the start time of the PMA.

5.4.3. The subcode-Q channel.

The encoding of the subcode-Q channel is: (see tables 5.4 and 5.5)

S0,S1	CONTR	ADR	TNO	POINT	MIN	SEC	FRAME	ZERO	PMIN	PSEC	PFRAME	CRC

S0, S1 : The coding rules are according to the Red Book, page 40.

CONTROL : see CONTROL in chapter 5.6.3.

TNO = 00

ZERO = 0..9: A counter which labels the successive frames in a unity of ten subcode frames. The first frame is labelled 0, the last is 9.

ADR : The value in ADR determines what kind of information is in the Item (see chapter 5.4.1).

= 1: 'Table of contents' Items: The track numbers, start-, and stop times of recorded tracks.
a) POINT=01..99: The value of POINT is n, when this recorded track has track number n.
b) The value of PMIN, PSEC, PFRAME gives the start time of the recorded track, pointed to by POINT.
c) The value of MIN, SEC, FRAME gives the stop time of the recorded track, pointed to by POINT.

= 2: The 'Disc Identification' Item. The use of this Item is optional. It may only be recorded once in the PMA. In this Item a six digit number is recorded which can be used for the identification of each disc. If not used, ADR=2 should not be present.
a) MIN, SEC, FRAME each contain a BCD encoded 2 digit number. The 6 digits together are the Disc Identification. This 6 digit number should be determined at random.
b) POINT, PMIN, PSEC, PFRAME are reserved and set to zero.

= 3: 'Skip Track' Item. The use of this Item is optional. In these Items maximally six track numbers can be noted which have to be skipped during play back. If not used, ADR=3 should not be present.
   a) POINT=01..21: The value of POINT is J, when this is the J^{th} 'Skip Track' assignment that is noted in the PMA.
   b) MIN, SEC, FRAME, PMIN, PSEC, PFRAME can each contain a track number of a track which has to be skipped during play back of the disc. If less than six tracks are noted, the remaining bytes have to be set to zero.

= 4: 'Unskip Track' Items. The use of this Item is optional. These Items are used to cancel a previously given 'Skip track' assignment. If not used, ADR=4 should not be present.
   a) POINT=01..21: The value of POINT is K, when this is the K^{th} 'Unskip Track' assignment that is noted in the PMA.
   b) MIN, SEC, FRAME, PMIN, PSEC, PFRAME each can contain a track number of a track which is noted previously in a 'Skip track' Item. This track will now be played back normally again. If less than six tracks are noted, the remaining bytes have to be set zero.

= 5: 'Skip Time Interval' Items. The use of this Item is optional. These Items are used to indicate that a time interval in the Program Area of the disc has to be skipped during play back. If not used, ADR=5 should not be present.
   a) POINT=01..40: The value of POINT is M, when this is the M^{th} 'Skip Time Interval' assignment that is noted in the PMA.
   b) The value of PMIN, PSEC, PFRAME gives the start time of the 'Skip Time Interval' number M, pointed to by POINT.
   c) The value of MIN, SEC, FRAME gives the stop time of the 'Skip Time Interval' number M, pointed to by POINT.

= 6: 'Unskip Time Interval' Items. The use of this Item is optional. These Items are used to cancel a previously given 'Skip Time Interval' assignment. If not used, ADR=6 should not be present.
   a) POINT=01..40: The value of POINT is N, when this is the N^{th} 'Unskip Time Interval' assignment that is noted in the PMA.
   b) MIN, SEC, FRAME, PMIN, PSEC, PFRAME each contain a number M of a time interval which is noted previously as 'Skip Time Interval' number M (see ADR=5). This time interval will now be played back normally again. If less than six numbers are noted, the remaining bytes have to be set to zero.

= 7..F: reserved.

Remarks:
   * Every recorder should react properly to at least the first 10 'Time Intervals' and the first 21 'Tracks' that should be skipped as a result of the complete skip information in the PMA.
   * When a disc is finalized, the skip information can be recorded in the Lead In Area (see chapter 5.5). The number of 'Skip Track' and 'Skip Time Interval' Items that can be noted in the Lead In Area are limited to maximally 40 Time Intervals and 21 Tracks.

5.5. Lead-in Area

The Lead-In Area contains information about the disc and about the recorded tracks.
In the Lead-In, information is encoded in Q-channel. The subcode-Q Modes are used according to the Red Book.
Mode 1 is always present. The format of Mode 1 is according to the Red Book, and contains the start positions of the recorded tracks. See chapter 5.5.2 Mode 1.
Mode 5 is optional, unless the disc is a Hybrid disc (see chapter 11).
Within Mode 5 the identification of the Hybrid disc is defined, see chapter 5.5.2 Mode 5. Optionally, Mode 5 contains information about recorded tracks or parts (time intervals) of recorded tracks that should be skipped during play back of the disc. Every recorder has to skip these parts of the disc.
If both Mode 1 and Mode 5 are present, they should be placed in alternating order, each subcode block being repeated three times. When used, Mode 1 and Mode 5 each occupy at least 3 out of 10 successive subcode blocks.
If the disc is no Hybrid Disc, and no skip information is recorded, Mode 5 should be filled with zero's if it is present.

5.5.1 ATIP/Subcode synchronization

In the Lead-in Area the ATIP time-code is identical to the time value encoded in MIN, SEC, FRAME of Subcode channel-Q.
The end of the Lead-in Area is encoded with a time-code of 99 Minutes, 59 Seconds, 74 Frames in both ATIP and Subcode-Q.

5.5.2 Table of Contents (see Table 5.6)

When finalizing the disc, the Table of Contents is written in the Lead In Area. After finalizing the disc, additional recording on the disc is not possible. The Table of Contents starts at the start-time of the Lead In Area as indicated in ATIP (see chapter 4.4).
In the TOC the Items are repeated three times each. The complete TOC is continuously repeated during the Lead-in Area. If Mode-1 and Mode-5 are both present, each Mode should be repeated separately (see Table 5.6). The Lead-In area stops at absolute time 99:59:74. This corresponds to diameter 50 +0.0/-0.4 mm.

S0, S1	CON TROL	ADR	00	POINT	MIN	SEC	FRAME	ZERO	PMIN	PSEC	P-FRAME	CRC
			TNO									

S0, S1 : According to the Red Book, page 40.
TNO : 00
CONTROL: See CONTROL in chapter 5.6.3

ADR = 1: Mode 1

MIN, SEC and FRAME indicate absolute time on the disc. They should be identical to ATIP-time.

ZERO is 00.

POINT = 01 .. 99
The value of PMIN, PSEC and PFRAME gives the start position of the recorded track pointed to by POINT.

POINT = A0
a) PMIN gives the value of the first recorded track number in the program area.
b) PSEC and PFRAME are 00.

POINT = A1
a) PMIN gives the value of the last recorded track number in the Program Area.
b) PSEC and PFRAME are 00.

POINT = A2
PMIN, PSEC and PFRAME gives the start position of the Lead-out Area.

CRC: 16 bit CRC on Control, ADR and Q-data (MSB first). On the disc the parity bits are inverted. The remainder have to be checked at zero. The check polynomial is:
$P(X) = X^{16} + X^{12} + X^5 + 1$

ADR = 5: Mode 5

POINT=B0
This pointer, together with POINT=C0 is used for the identification of the Hybrid Disc.
If the disc is not a Hybrid Disc, POINT=B0 is not present.
a) MIN, SEC, FRAME give the start time of the next possible Program Area in the Recordable Area of the Hybrid Disc.
b) PMIN, PSEC, PFRAME give the maximum start time of the outermost Lead Out Area in the Recordable Area of the Hybrid Disc.
c) ZERO gives the number of different pointers present in Mode 5.

POINT = B1
a) MIN, SEC, FRAME, ZERO, PFRAME = 00
b) PMIN gives the number N (N≤40) of Skip Interval Pointers (POINT=01..N).
c) PSEC gives the number M (M≤21) of Skip Track assignments in POINT=B2..B4.
If no Skip Interval Pointers and no Skip Track assignments are used, POINT=B1 is not present.

POINT = B2..B4
MIN, SEC, FRAME, ZERO, PMIN, PSEC, PFRAME each give a value of a track number that should be skipped during play back. Remaining, unused bytes within a block should be filled with 00. If not used at all, POINT=B2..B4 is not present.

POINT = 01..40
These are the Skip Interval Pointers. They indicate an Interval (time interval) on the recorded disc that should be skipped during play back. Intervals should be noted chronologically. The number N of used Skip Interval Pointers

is given in POINT=B1. If no Skip Interval Pointers are used (N=0), POINT=01..40 should not be present.

a) The value of PMIN, PSEC, PFRAME gives the start time of an Interval on the disc that should be skipped during play back.
b) The value of MIN, SEC, FRAME gives the stop time of the Interval indicated in a).
c) ZERO = 00: reserved

POINT = C0

This pointer, together with POINT=B0, is used for the identification of a Hybrid Disc.
POINT=C0 is only present in the first Lead In Area of a Hybrid Disc.

a) MIN : A value for the optimum recording power of this disc. This value should be copied from the value, encoded in ATIP during the Lead In Area (see chapter 4.4 in the specially encoded ATIP frames with MSB combination 101, in the 'Minutes' byte).

```
Bit 7..5 :  Recommended optimum recording power.
         =  000   : 4.0 mW
         =  001   : 4.4
         =  010   : 4.9
         =  011   : 5.4
         =  100   : 5.9
         =  101   : 6.6
         =  110   : 7.2
         =  111   : 8.0
Bit 4..0 =  00000 : reserved
```

b) SEC : The Disc Application Code. This value should be copied from the value, encoded in ATIP during the Lead In Area (see chapter 4.4 in the specially encoded ATIP frames with MSB combination 101, in the 'Seconds' byte).

```
Bit 7..1     : Disc Application Code
   Bit 7 = 0 : Disc for restricted use.
               Bit 6..1 = 000000: General Purpose Disc.
               Bit 6..1 = others: Special Purpose Disc.
                                  Reserved for the encoding of
                                  Special disc Applications.
   Bit 7 = 1 : Disc for unrestricted use.
               Bit 6..1 = 000000: reserved
Bit 0    = 0 : reserved
```

c) FRAME, ZERO: reserved and set to zero.
d) PMIN, PSEC, PFRAME give the start time of the first Lead In Area of the Hybrid Disc.

CRC: 16 bit CRC on CONTROL, ADR and Q-data (MSB first). On the disc the parity bits are inverted. The remainder have to be checked at zero.
The check polynomial is:

$$P(X) = X^{16} + X^{12} + X^{5} + 1$$

Remark:
Different Skip Intervals should not overlap each other when they are noted in the Lead In Area, and Skip Intervals should not overlap Skip Track assignments.

5.6. Program Area

The Program Area consists of the recorded tracks. The starting diameter is 50 +0.0/-0.4 mm ; the maximum outer diameter is 116 mm.

5.6.1. ATIP/Subcode synchronization

In the Program Area the ATIP time-code is identical to the Subcode-Q absolute time (AMIN, ASEC, AFRAME).
The first ATIP and Subcode-Q time-code in the Program Area is zero (0 Minutes, 0 Seconds, 0 Frames).

5.6.2. Subcode/Header synchronization

The Header address and the Subcode-Q absolute time before CIRC/EFM encoding are identical.

5.6.3. Subcode Q-Channel

The Q-channel data in the Program Area are basically according to the Red Book :

S0, S1	CONTROL	ADR 1	TNO	INDEX	MIN	SEC	FRM	ZERO	AMIN	ASEC	A-FRAME	CRC

TNO, INDEX : track- and index-number

AMIN, ASEC, AFRM : absolute time in-line with ATIP of unrecorded disc

MIN, SEC, FRM : relative time within a track.

ZERO : bit 7..0 = 00000000 : reserved

CONTROL : Identification of the kind of information within a Track (bit 3 is first bit and MSB)

bit 3..0 = 00x0: 2 audio channels without pre-emphasis
= 00x1: 2 audio channels with pre-emphasis
= 01x0: Data track, recorded uninterrupted.
= 01x1: Data track, recorded incrementally.
= 10x0: reserved
= 10x1: reserved
= 11x0: reserved
= 11x1: reserved

bit 1 : This 'Copy bit' is continuous 1, continuous 0, or alternating 1 and 0.
= continuous 0 : track is copy-right protected.
= continuous 1 : track is not copy-right protected, and copying is permitted.
= alternated 1/0: track is first or higher generation copy of a copy-right protected track. The frequency for alternating between 1 and 0 is 9.375 Hz (duty-cycle 50%), which means successively four subcode frames 1 and four frames 0. This alternating bit should be used on discs 'for unrestricted use' (see chapter 4.4).

5.6.4. P, R..W Subcode channels

The P-bit = 1 for the first two seconds in the Program Area. For the remainder of the disc, the P-bit should be either set to zero or be used as specified in the Red Book.
The channels R..W are according to the Red Book. If they are not used they should be zero. In the PMA the channels R..W are reserved, and set to zero.

5.6.5. Data Tracks.

Every Data track must start with a Pre Gap.

5.6.5.1. The Pre Gap.

The definition of the Pre Gap is according to the Yellow Book or Green Book, unless it is specified different in this chapter. The definition of the Post Gap is according to the Yellow Book or the Green Book.
The second part of the Pre Gap is characterized by:

a: In the Q-channel:
   * INDEX = 00
   * Relative time (MIN, SEC, FRAME) decreases to 00:00:00 at the end of the Pre Gap.

b: In the main channel:
   * The data is block encoded according to one of the Mode numbers as specified in the Yellow Book and the Green Book. A block in the second part of the Pre Gap is called a Track Descriptor Block.
   * The Track Descriptor Block is repeated continuously during the second part of the Pre Gap.

5.6.5.2. The Track Descriptor Block (see Table 5.7).

The Track Descriptor Block contains in the User Data Field information about the track attributes of the current track. Optionally it contains the track attributes of all the preceding tracks.
The User Data Field within a Track Descriptor Block consists of two parts:

a: Track Descriptor Table. This table is at the beginning of each User Data Field and is eight bytes long (see chapter 5.6.5.3).
b: One or more Track Descriptor Units. A unit consists of sixteen bytes. The first Track Descriptor Unit is placed directly after the Track Descriptor Table (see chapter 5.6.5.4).

Non used bytes between the end of the last Track Descriptor Unit and the end of the User Data field of a Track Descriptor Block are filled with zero.

5.6.5.3. The Track Descriptor Table.

The contents of these eight bytes in the main channel are (see Table 5.7):

Byte 0..2 : Track Descriptor Identification. These three bytes contain the Hexadecimal code: 54 44 49 (ASCII TDI).
Byte 3..4 : Pre Gap length. The number of blocks of the second part of this Pre Gap, encoded in BCD.
Byte 5 : Indicates which Track Descriptor Units are present.
= 00 : Indicates that Track Descriptor Units of previous tracks are present in this Track Descriptor Block.
= 01 : Indicates that Track Descriptor Units of

previous tracks are not present in this Track Descriptor Block.
= others : reserved.

Byte 6 : The lowest tracknumber described in this Track Descriptor Block, encoded in BCD.

Byte 7 : The highest tracknumber described in this Track Descriptor Block, encoded in BCD.

5.6.5.4. The Track Descriptor Unit.

A Track Descriptor Unit consists of 16 bytes in the main channel. They describe the Data attributes of each track. The contents of these 16 bytes are (see Table 5.7):

Byte 0 : Track number, BCD encoded.

Byte 1 : Write method of the track.
Bit 7..4 = 1000 : Uninterrupted written Data track. The track consists of only one Packet.
Bit 3..0 : Reserved and set to zero.

= 1001 : Incremental written Data track. The track consists of more than one Packet.
Bit 3..0 = 0000 : variable Packet Size.
= 0001 : fixed Packet Size.
= other: Reserved.

= 0000 : Uninterrupted written Audio track.
Bit 3..0 : Reserved and set to zero.

= other: Reserved.
Bit 3..0 = Reserved.

Byte 2..4 : Packet Size.
a: For Incremental written tracks with fixed Packet Size (Byte 1=91), these bytes contain the BCD encoded Packet Size.
b: For Incremental written tracks with variable Packet Size (Byte 1=90), and Uninterrupted written Data Tracks (Byte 1=80), these three bytes contain the code FF FF FF.

Byte 5..7 : Logic start address (see Figure 5.8).
The hexadecimal encoded logical block number of the first User Data block within the track.
This logical block number is calculated from the number of blocks in all previous tracks:
* In case of a track with fixed Packet Size, only the User Data blocks should be counted.
* In case of a track with variable Packet Size, all physical blocks should be counted, including the Run-in, Run-out and Link blocks but excluding the Pre Gap.

* In case of an uninterrupted written track, all physical blocks should be counted, excluding the Run-out blocks and the Pre Gap.

The counting of the logical block numbers starts with zero.

Byte 8..15 : Reserved and set to zero.

5.6.6. ATIP/Header synchronization

The start of a Block-Sync (before encoding) is within -10 and +36 EFM frames after the (detected) ATIP Sync. (see fig.5.2).

5.7. Recordable User Area + Lead-out Area

5.7.1. Recordable User Area

This is the remaining blank area of the disc that is reserved for the recording of additional Tracks with user information.
Additional recording must start directly after the last recording, according to the linking rules for Incremental Writing (see chapter 5.2 and Fig. 1.2).

5.7.2. Lead-Out Area

The recorded EFM in the Lead-out Area is encoded according to the rules given in the Red Book.
The last possible start-time of the Lead-Out is encoded in ATIP (see chapter 4.4).
The Lead Out Area is at least 1.0 mm in diameter wide, with a minimum possible recording time of 1.5 minutes.

5.7.2.1. ATIP/Subcode synchronization

In the Lead-out Area the ATIP time-code is identical to the Subcode-Q absolute time (AMIN, ASEC, AFRAME).

6. EFM Modulation system

See Red Book pages 13 up to and including 26.

7. CIRC Error correction system

Audio tracks : See Red Book pages 27 up to and including 38.
Data tracks : See Yellow Book pages 27 up to and including 38.

8. Control and display system

Audio tracks : See Red Book "CONTROL AND DISPLAY SYSTEM".
Data tracks : See Yellow Book "CONTROL AND DISPLAY SYSTEM".

9. Audio specification

See Red Book pages 1 and 1a.

10. Digital data structure

See Yellow Book pages 1, 1a and 100 up to and including 112.

11. Hybrid disc.

11.1 Introduction.

For Data applications, a Hybrid disc is defined as a disc which consists of both an area with pre-mastered or pre-recorded user information and a recordable area where additional recordings can be made.
The lay-out of this disc is given in Figure 11.1 and Figure 11.2.
It consists of two area's:

* Pre-mastered Area or Pre-recorded Area (see chapter 11.2).
* Recordable Area (see chapter 11.3).

The lay-out of a disc with pre-mastered user information is the same as for a disc with pre-recorded information. The only difference is the way they are produced. For both discs the user information is recorded according to the Yellow Book or Green Book and the signals should fulfill the requirements as stated before in this Orange Book Part II.
When it has a Pre-recorded Area with user information, it is basically a finalized, recorded disc as described previously in this Orange Book Part II, with an additional recording possibility outside of the pre-recorded area of the disc.
The definition of the Hybrid Disc allows for the finalization of recorded parts of related information (e.g. a certain number of tracks). Such a finalized part, consisting of a Lead In Area, Program Area and Lead Out Area is called a Volume. Each Volume is Yellow Book or Green Book compatible.
As a result of this, there may be more than one Program Area in the recordable part of the Hybrid Disc.

Remark 1:
Not all Data recorders or read only players are able to use all possibilities of the Hybrid Disc. Only the read out of the first Volume on a Hybrid Disc will always be possible.

Remark 2:
The maximum allowed variations of Push Pull amplitude and reflectivity on one disc, are allowed to be fulfilled separately for the entire Pre-recorded or Pre-mastered Area and the entire Recordable Area.

11.2 Pre-mastered Area or Pre-recorded Area.

The information in the pre-mastered or pre-recorded area of the disc is recorded according to the Yellow Book or the Green Book. All signals should fulfill all requirements as specified before in this Orange Book Part II.
The identification of the Hybrid Disc is in Mode 5 of the subcode-Q channel in the Lead In Area of the pre-mastered or pre-recorded area of this disc (see chapter 5.5.2).

11.3 Recordable Area.

Within the Recordable Area, all signals should fulfill the requirements as stated before in this Orange Book Part II, except for the next specification items with modified requirements:
chapter 2.2, paragraph 15.4 : Jitter < 40 ns.
chapter 2.2, paragraph ad 15.1: Push Pull amplitude 0.04 - 0.11.
chapter 2.2, paragraph 18.3 : Wavelength read spot $775 < \lambda < 800$ nm.

An example of the lay out of the Recordable Area is shown in Figure 11.1.
The Recordable Area consists of three area's:
1: Power Calibration Area (PCA).
2: Program Memory Area (PMA).
3: Area for user recordings. In this area the user can record different Program Area's with their matching Lead In Area's and Lead Out Area's.
The PCA, PMA, Lead In Area, Program Area and Lead Out Area are described below.

11.3.1 PCA and PMA.

Both the PCA and PMA are according to the definitions in chapter 5.3 and 5.4.

11.3.2 Lead In Area.

The recording of the data in the Lead in Area is according to the definitions in the Yellow Book or the Green Book and must fulfill the requirements as stated before in this Orange Book Part II. The only difference is that the subcode-Q time should not be 99:59:74 at the end of the Lead In Area but should be a copy of ATIP.
The Lead In Area of Volume X starts 01:00:00 before the start of the Program Area of Volume X, and contains the data on this Program Area. It ends at the start of this Program Area.

11.3.3 Program Area.

The recording of the data in the Program Area is according to the definitions in the Yellow Book or the Green Book and must fulfill the requirements as stated in the Orange Book Part II.
The first Program Area starts 01:00:00 after the end of the Lead Out Area in the Pre-mastered or Pre-recorded Area. The start time of Program Area in Volume X is encoded in Mode 5 of the Lead In Area in Volume X-1.
The first track number in Volume X is 1 higher than the last track number in Volume X-1. Maximally 99 tracks can be recorded on the entire disc.
Before a disc leaves the recorder, all Volumes must be finalized. Outside the last finalized Volume there might exist a partially recorded area (e.g. Program Area 4 in Figure 11.1).

11.3.4 Lead Out Area.

The encoding of the Lead Out Area is according to the Yellow Book or the Green Book.
The length of the Lead Out Area is 00:30:00 in time.
The last possible start time of the outermost Lead Out Area is encoded in Mode 5 of the Lead In Area.

Page 36 to 39 is intentionally left blank.

FIGURES and tables

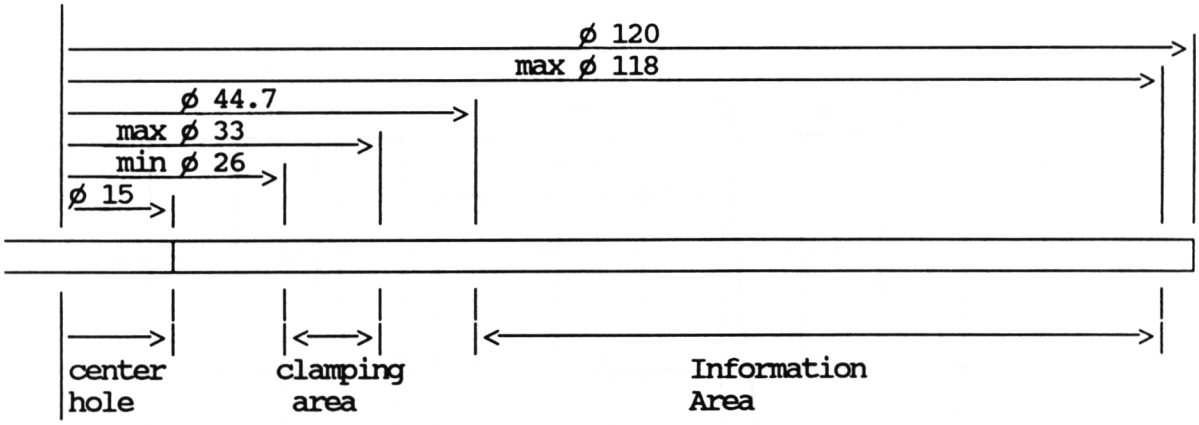


Figure 1.1 : Layout of the Unrecorded disc

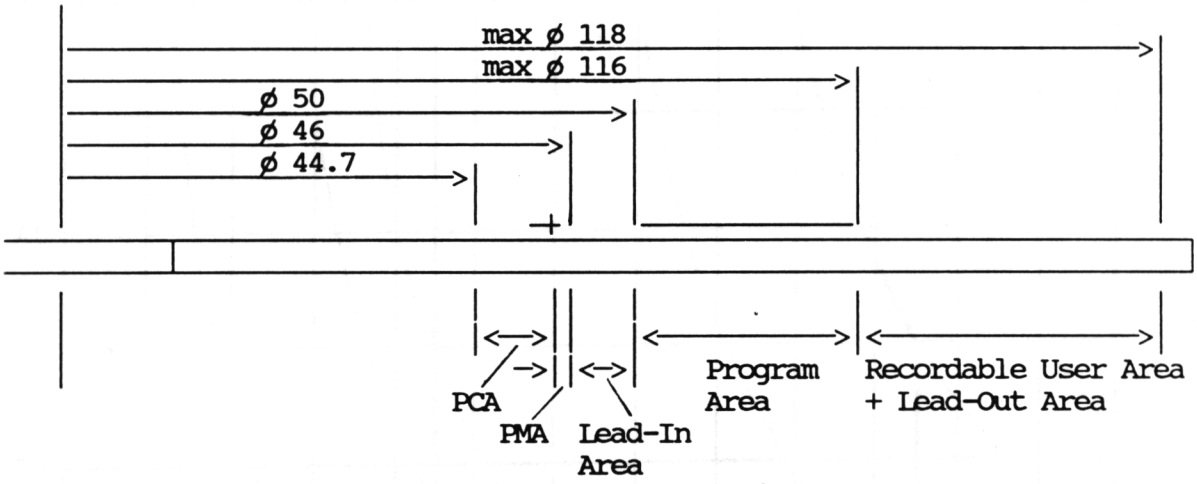


Figure 1.2 : Layout of the Partially Recorded disc
—— (above disc surface): recorded part.

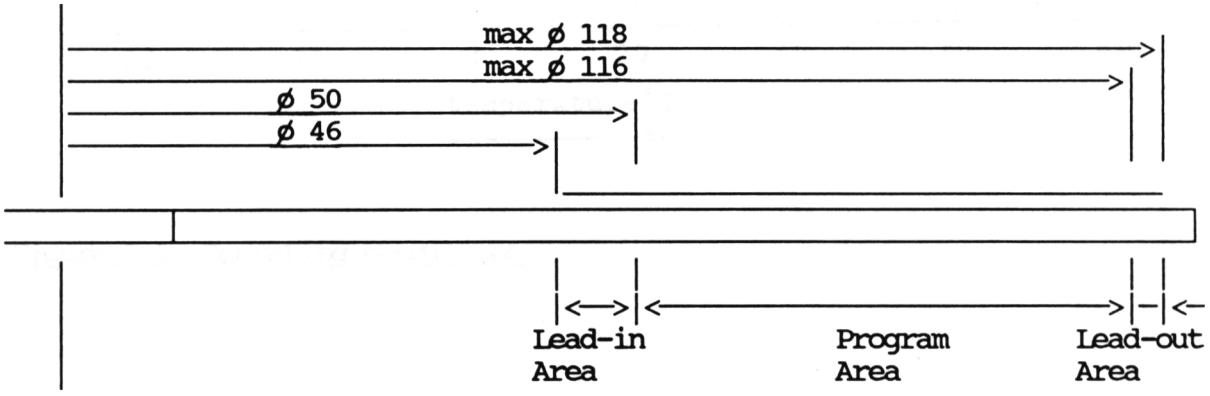


Figure 1.3 : Layout of the Recorded disc
—— (above disc surface): recorded part.

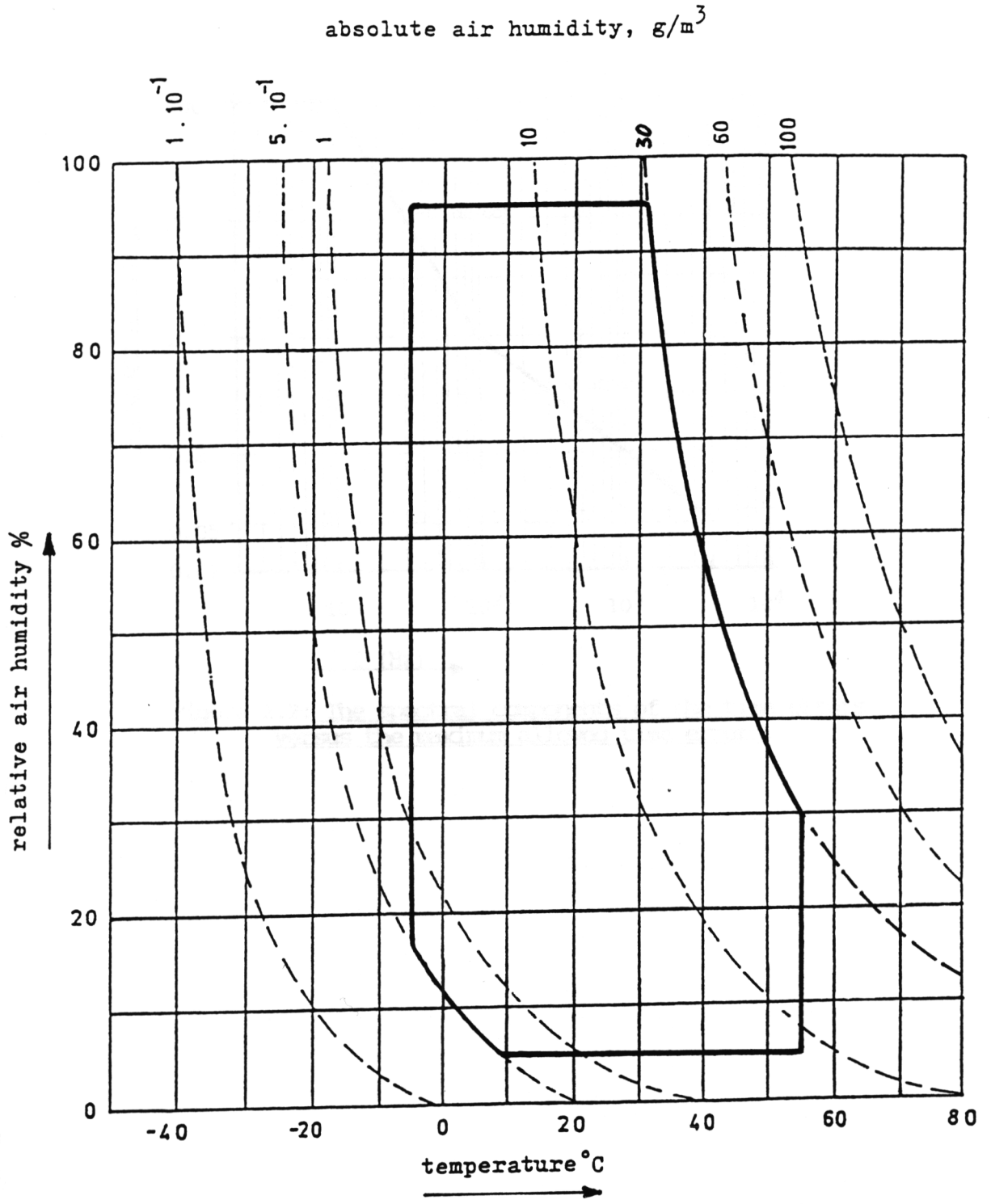


Figure 2.1: Operating conditions.

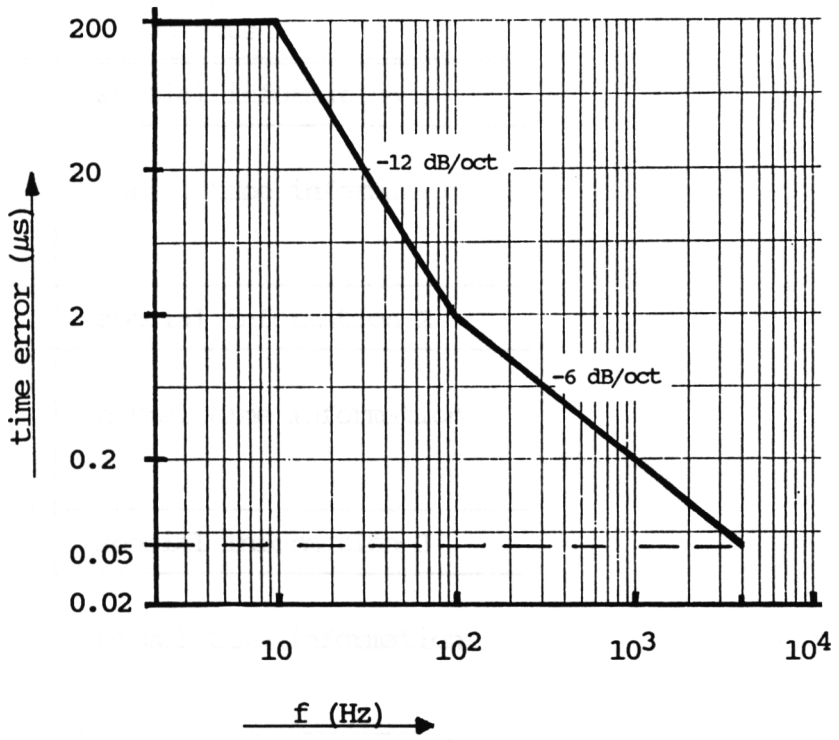


Figure 2.2: The spectral components of the time errors versus the maximum allowed time errors.

frame number	frame contents
0	special information 1
1 . . 9	normal time information
10	special information 2
11 . . 19	normal time information
20	special information 3
21 . . 29	normal time information
30	special information 1
31 . . 39	normal time information
40	special information 2
41	

Figure 4.1: Encoding of ATIP frames in the Lead-In Area.

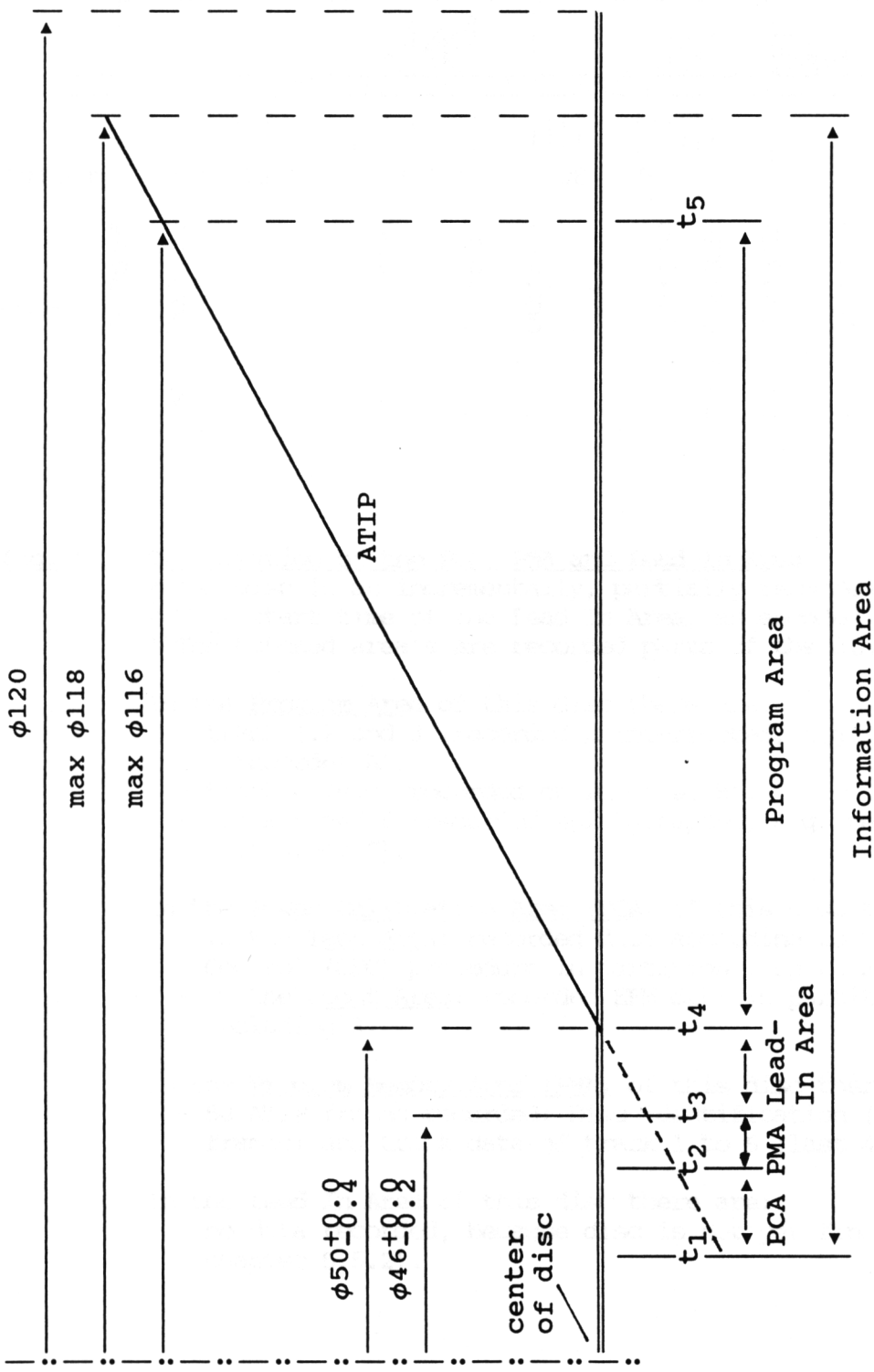


Fig.4.2: ATIP versus disc diameters.

t_1 = start time PCA = t_3 - 00:35:65
t_2 = start time PMA = t_3 - 00:13:25
t_3 = start time Lead-In Area = encoded in ATIP
t_4 = start time Program Area = 00:00:00
= end time Lead-In Area = 99:59:74
t_5 = last possible start time Lead-Out Area = encoded in ATIP

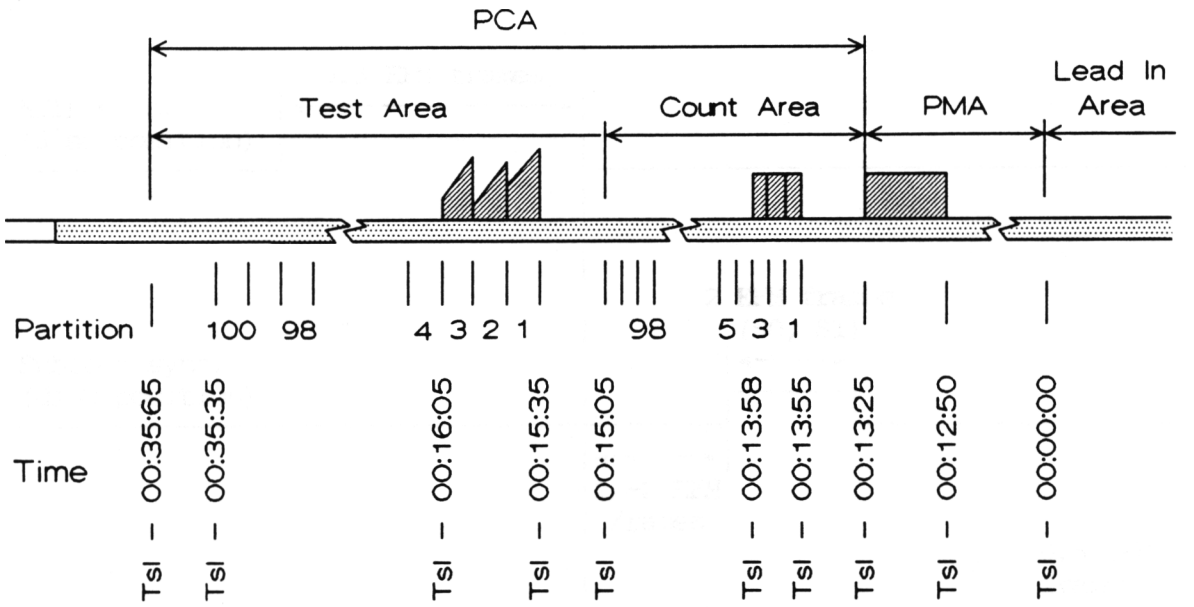


Fig. 5.1: Organization of the PCA, PMA and Lead In Area.

* The disc is an incrementally, partially recorded CD-WO disc.
* T_{sL}= start time of the Lead In Area, as encoded in ATIP.
* The hatched area's are recorded parts of the disc.

In the **Program Area** of this disc there are:
- track 1,2 and 3 (recorded uninterrupted, e.g. recorded on recorder A).
- track 4 (e.g. recorded on recorder B).
- track 5 and 6 (recorded uninterrupted, e.g. recorded on recorder C).

In the **Power Calibration Area (PCA)** of this disc there are:
- In the Test Area: recorded data according to Optimum Power Control (OPC) procedure in partition 1 up to and including 3.
- In the Count Area: recorded EFM data in partition 1 up to and including 3.

In the **Program Memory Area (PMA)** of this disc there are:
- 50 ATIP frames recorded: Disc Identification (first 10 frames) and track data of track 1 to 6 (last 40 frames).

In the **Lead In Area** of this disc there are:
- no data recorded, because disc is not yet finalized (see chapter 5.5.2).

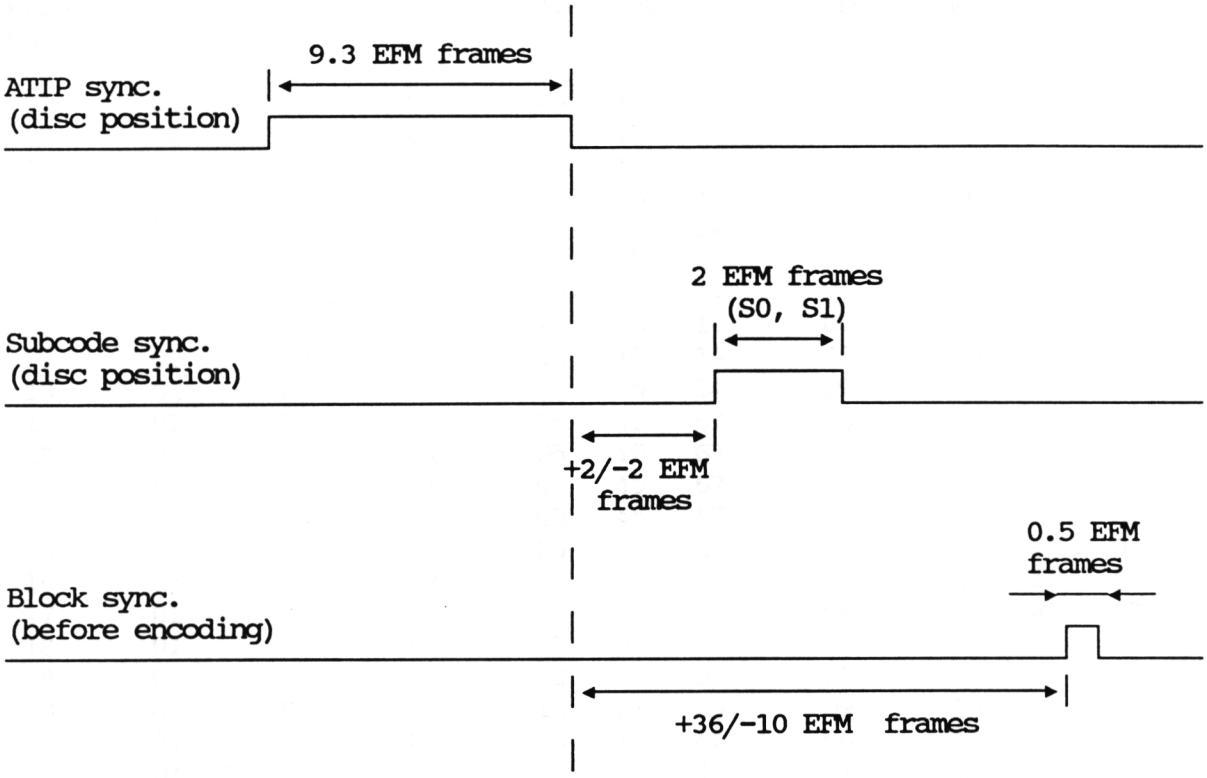


Figure 5.2: Synchronization rules.

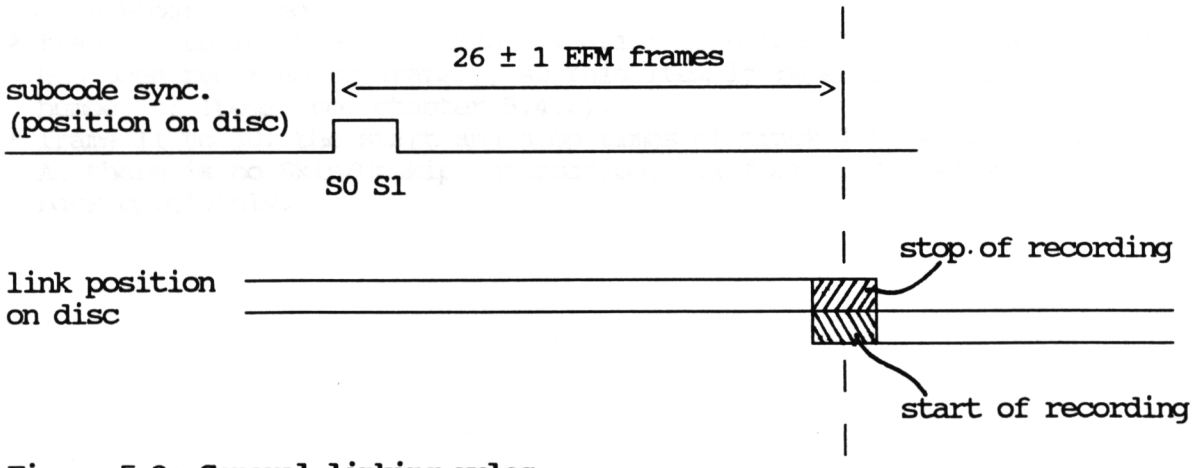


Figure 5.3: General linking rules

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
1	02	00	00	20	15	14	00	00	00	00
2	02	00	00	20	15	14	01	00	00	00
3	02	00	00	20	15	14	02	00	00	00
4	02	00	00	20	15	14	03	00	00	00
5	02	00	00	20	15	14	04	00	00	00
6	02	00	00	20	15	14	05	00	00	00
7	02	00	00	20	15	14	06	00	00	00
8	02	00	00	20	15	14	07	00	00	00
9	02	00	00	20	15	14	08	00	00	00
10	02	00	00	20	15	14	09	00	00	00
11	01	00	01	05	45	67	00	00	02	01
12	01	00	01	05	45	67	01	00	02	01
13	01	00	01	05	45	67	02	00	02	01
14	01	00	01	05	45	67	03	00	02	01
15	01	00	01	05	45	67	04	05	02	01
16	01	00	02	12	01	09	05	05	45	67
17	01	00	02	12	01	09	06	05	45	67
18	01	00	02	12	01	09	07	05	45	67
19	01	00	02	12	01	09	08	05	45	67
20	01	00	02	12	01	09	09	05	45	67
21	01	00	03	30	17	42	00	12	01	09
22	01	00	03	30	17	42	01	12	01	09
23	01	00	03	30	17	42	02	12	01	09
24	01	00	03	30	17	42	03	12	01	09
25	01	00	03	30	17	42	04	12	01	09
26	01	00	04	37	50	18	05	30	17	42
27	01	00	04	37	50	18	06	30	17	42
28	01	00	04	37	50	18	07	30	17	42
29	01	00	04	37	50	18	08	30	17	42
30	01	00	04	37	50	18	09	30	17	42
31 etc.: unrecorded										

Table 5.4: Program Memory Area (example 1)

Example of encoding of the PMA of CD-WO disc number 201514, with 4 tracks in the Program Area.

* frame 1 to 10: the Disc Identification is noted. In this case, this Item has been recorded separately, so this Item is repeated 10 times (uneven number of Items, see chapter 5.4.2).
* frame 11 to 30: the start and stop times of track 1 to 4 are noted. As there is no Skip/Unskip information, all four tracks will be played back completely.

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
1	02	00	00	20	15	14	00	00	00	00
..	..	..	..	..	..	..	..	..	..	..
10	02	00	00	20	15	14	09	00	00	00
11	01	00	01	05	45	67	00	00	02	01
12	01	00	01	05	45	67	01	00	02	01
13	01	00	01	05	45	67	02	00	02	01
14	01	00	01	05	45	67	03	00	02	01
15	01	00	01	05	45	67	04	05	02	01
16	01	00	02	12	01	09	05	05	45	67
17	01	00	02	12	01	09	06	05	45	67
18	01	00	02	12	01	09	07	05	45	67
19	01	00	02	12	01	09	08	05	45	67
20	01	00	02	12	01	09	09	05	45	67
21	01	00	03	30	17	42	00	12	01	09
22	01	00	03	30	17	42	01	12	01	09
23	01	00	03	30	17	42	02	12	01	09
24	01	00	03	30	17	42	03	12	01	09
25	01	00	03	30	17	42	04	12	01	09
26	01	00	04	37	50	18	05	30	17	42
27	01	00	04	37	50	18	06	30	17	42
28	01	00	04	37	50	18	07	30	17	42
29	01	00	04	37	50	18	08	30	17	42
30	01	00	04	37	50	18	09	30	17	42
31	03	00	01	02	03	04	00	00	00	00
32	03	00	01	02	03	04	01	00	00	00
33	03	00	01	02	03	04	02	00	00	00
34	03	00	01	02	03	04	03	00	00	00
35	03	00	01	02	03	04	04	00	00	00
36	05	00	01	05	45	67	05	05	42	67
37	05	00	01	05	45	67	06	05	42	67
38	05	00	01	05	45	67	07	05	42	67
39	05	00	01	05	45	67	08	05	42	67
40	05	00	01	05	45	67	09	05	42	67
41	01	00	05	42	16	32	00	37	50	18
42	01	00	05	42	16	32	01	37	50	18
43	01	00	05	42	16	32	02	37	50	18
44	01	00	05	42	16	32	03	37	50	18
45	01	00	05	42	16	32	04	37	50	18
46	04	00	01	03	04	00	05	00	00	00
47	04	00	01	03	04	00	06	00	00	00
48	04	00	01	03	04	00	07	00	00	00
49	04	00	01	03	04	00	08	00	00	00
50	04	00	01	03	04	00	09	00	00	00
51 etc.: unrecorded										

Table 5.5: Program Memory Area (example 2).
Example of encoding of the PMA of CD-WO disc number 201514, with 5 tracks in the Program Area.
* frame 1 to 30: see Table 5.4
* frame 31 to 35: tracks 2, 3 and 4 are noted to be skipped.
* frame 36 to 40: Time Interval number 1 is noted to be skipped.
* frame 41 to 45: start and stop time of track 5 is noted.
* frame 46 to 50: tracks 3 and 4 are unskipped.

As a result, track 1, 3, 4, 5 will be played back. Track 2 and the last three seconds of track 1 will be skipped.

Frame Number	CONTROL & ADR	TNO	POINT	MIN	SEC	FRM	ZERO	PMIN	PSEC	PFRM
n	01	00	A0	absolute time			00	01	00	00
n+1	01	00	A0	absolute time			00	01	00	00
n+2	01	00	A0	absolute time			00	01	00	00
n+3	05	00	B1	00	00	00	00	03	01	00
n+4	05	00	B1	00	00	00	00	03	01	00
n+5	05	00	B1	00	00	00	00	03	01	00
n+6	01	00	A1	absolute time			00	05	00	00
..	..	..	..	..	..	..	..	..	..	..
n+9	05	00	B2	03	00	00	00	00	00	00
..	..	..	..	..	..	..	..	..	..	..
n+12	01	00	A2	absolute time			00	42	16	32
..	..	..	..	..	..	..	..	..	..	..
n+15	05	00	01	05	45	67	00	05	42	67
..	..	..	..	..	..	..	..	..	..	..
n+18	01	00	01	absolute time			00	00	02	01
..	..	..	..	..	..	..	..	..	..	..
n+21	05	00	02	37	53	00	00	37	50	18
..	..	..	..	..	..	..	..	..	..	..
n+24	01	00	02	absolute time			00	05	45	67
..	..	..	..	..	..	..	..	..	..	..
n+27	05	00	03	42	16	32	00	42	14	00
..	..	..	..	..	..	..	..	..	..	..
n+30	01	00	03	absolute time			00	12	01	09
..	..	..	..	..	..	..	..	..	..	..
n+33	05	00	B1	00	00	00	00	03	01	00
..	..	..	..	..	..	..	..	..	..	..
n+36	01	00	04	absolute time			00	30	17	42
..	..	..	..	..	..	..	..	..	..	..
n+39	05	00	B2	03	00	00	00	00	00	00
..	..	..	..	..	..	..	..	..	..	..
n+42	01	00	05	absolute time			00	37	50	18
..	..	..	..	..	..	..	..	..	..	..
n+45	05	00	01	05	45	67	00	05	42	67
..	..	..	..	..	..	..	..	..	..	..
n+48	01	00	A0	absolute time			00	01	00	00
..	..	..	..	..	..	..	..	..	..	..
n+51	05	00	02	37	53	00	00	37	50	18
..	..	..	..	..	..	..	..	..	..	..
n+54	01	00	A1	absolute time			00	05	00	00
..	..	..	..	..	..	..	..	..	..	..
n+57 etc.										

Table 5.6: Table of Contents in the Lead In Area.

Example of encoding of the TOC for a CD-WO disc with 5 tracks in the Program Area. Track 3 and three Time Intervals should be skipped at play back.

* frame n to n+44: one complete encoding of Mode-1 (ADR=1), alternated with Mode-5 encoding.
* frame n+3 to n+29: one complete encoding of Mode-5 (ADR=5), alternated with Mode-1 encoding.

Byte	Contents	Byte	Contents	Byte	Contents	Byte	Contents
1	54						
2	44						
3	49						
4	01						
5	50						
6	00						
7	01						
8	04						
9	04	25	01	41	02	57	03
10	80	26	91	42	91	58	90
11	FF	27	00	43	00	59	FF
12	FF	28	00	44	00	60	FF
13	FF	29	32	45	64	61	FF
14	00	30	00	46	00	62	00
15	08	31	00	47	01	63	06
16	C3	32	00	48	40	64	43
17	00	33	00	49	00	65	00
18	00	34	00	50	00	66	00
19	00	35	00	51	00	67	00
20	00	36	00	52	00	68	00
21	00	37	00	53	00	69	00
22	00	38	00	54	00	70	00
23	00	39	00	55	00	71	00
24	00	40	00	56	00	72	00
						73	00
						..	00
						..	00
						2048	00

Table 5.7: The User Data Field in the Track Descriptor Block of data track 4 (Mode=1).

* Byte number 1 to 8 is the Track Descriptor Table of track 4.
* Byte number 9 to 24 is the Track Descriptor Unit 1 (track 4).
* Byte number 25 to 40 is the Track Descriptor Unit 2 (track 1).
* Byte number 41 to 56 is the Track Descriptor Unit 3 (track 2).
* Byte number 57 to 72 is the Track Descriptor Unit 4 (track 3).
* The Pre Gap is 2 seconds (150 blocks) long.
* The Pre Gap also contains the Track Descriptors of track 1, 2, and 3.
* Track 4 is written Uninterrupted.
* Track 1, is Incremental written with a fixed Packet Size of 32 User Data Blocks. As an example, the track is 10 Packets long.
* Track 2, is Incremental written with a fixed Packet Size of 64 User Data Blocks. As an example, the track is 20 Packets long.
* Track 3 is Incremental written with a variable Packet Size. It is 640 blocks long (excluding the Pre Gap).

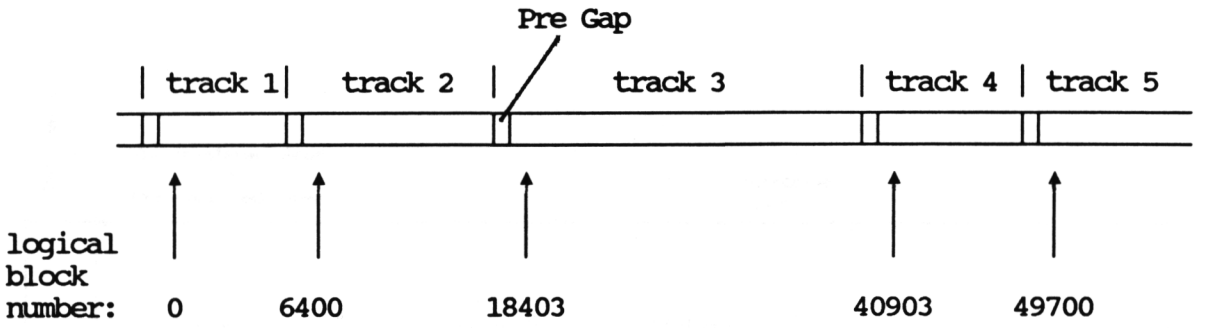


Figure 5.8: The Logic Start Address in Data tracks.

Track 1: Fixed Packet Size
100 packets long
Packet Size: 64 User Data Blocks/Packet:
Logic Start Address: 000000 (first logical blocknumber is 0: see chapter 5.6.5.4, byte 5..7).

Track 2: Fixed Packet Size
100 packets long
Packet Size: 120 User Data Blocks/Packet
Logic Start Address: 001900 (first user data block is 6400: 0 + 100*64 data blocks)

Track 3: Variable Packet Size
22500 blocks long (excluding Pre Gap)
Logic Start Address: 0047E3 (first user data block is 18403: 6400 + 100*120 data blocks + 3 run-in/link blocks)

Track 4: Variable Packet Size
8800 blocks long (excluding Pre Gap)
Logic Start Address: 009FC7 (first user data block is 40903: (18403 - 3)* + 22500 blocks + 3 run-in/link blocks)

Track 5: Fixed Packet Size
Logic Start Address: 00C224 (first user data block is 49700: (40903 - 3)* + 8800 blocks)

* : The 'Logic Start Address' of a track is calculated from the sum of all blocks with a logical block number in the previous tracks. The value between brackets is the first block with a logical block number of the previous track. Depending on the way the track is recorded, the 3 run-in/link blocks have a logical block number (variable packet size) or not (fixed packet size). See chapter 5.6.5.4, byte 5..7).

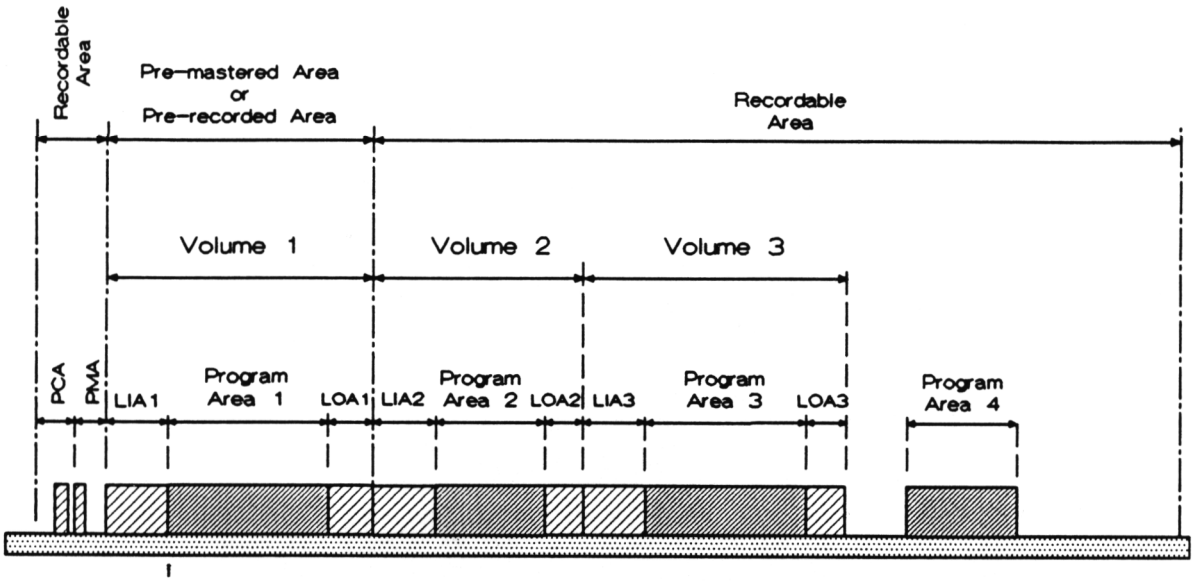


Fig. 11.1: Example of the layout of the Hybrid Disc.
(LIA=Lead In Area, LOA=Lead Out Area)

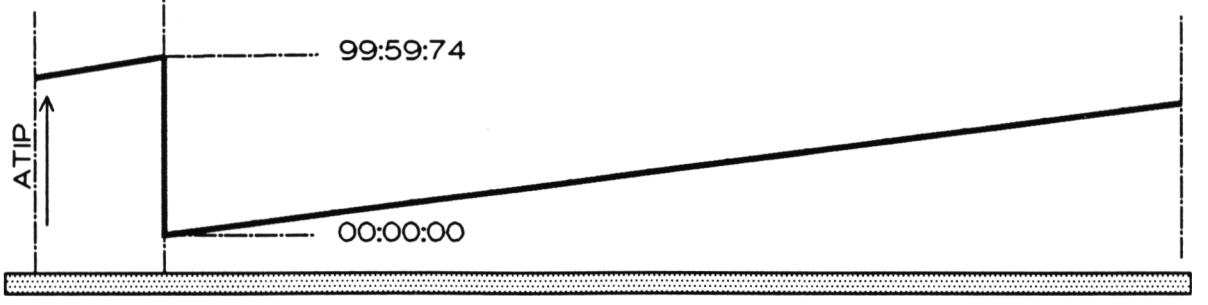


Fig.11.2: Absolute time on the Hybrid Disc.

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ATTACHMENT B: Recommendations and clarifications

B1. Principles of operation.

Recorded information:

In the Information Area, the CD-WO disc contains a spiral shaped groove in the sensitive layer. This groove is not a perfect spiral, but is wobbled in order to obtain motor control and timing information.
Recording takes place in the groove by locally heating up the sensitive layer with a laser spot. The laser output is modulated with the information to be recorded.
The parts of the disc that were heated up during recording show a reflection decrease after recording, and are called pits.
The encoded Audio or Data information is stored in the length of these pits and in the distance between them. In the digital system, these lengths and distances only take discrete values.

During playback of the disc, the scanning light spot is diffracted by the recorded pits in the sensitive layer. The optical power that is diffracted back into the objective lens, is modulated according to the encoded Audio or Data information. The modulated photo current is called the High Frequency (HF) signal.

The requirements for a recorded CD-WO disc (see Orange Book Part Two) are nearly the same as the requirements for a conventional CD disc (see Red Book). Therefore the recorded CD-WO disc can be played back on any conventional CD-player.

Tracking Information:

An off-track position of the scanning spot results in a diffraction pattern that is asymmetrical in the radial direction of the disc. Subtraction of the powers diffracted into the two halves of the aperture of the objective lens yields a servo signal for track following.

B2. Measurement of the disc reflectivity.

The reflectivity of a CD-WO disc is measured on a set-up as given in Fig.B2.1. The requirements for this set-up are in the Orange Book Part II chapter 2.: The Read Only Optical Pick Up. Non polarizing optics should be used.
A small detector is used (e.g. as in a normal player).

Note: Because of this small detector, the light reflected at the substrate, and the multiple reflections in the substrate are not included in reflectivity measurements.
When a different set-up than the above mentioned is used (e.g. parallel beam, large area detector, different wavelength, ...), compensations should be made to obtain the correct reflectivity.

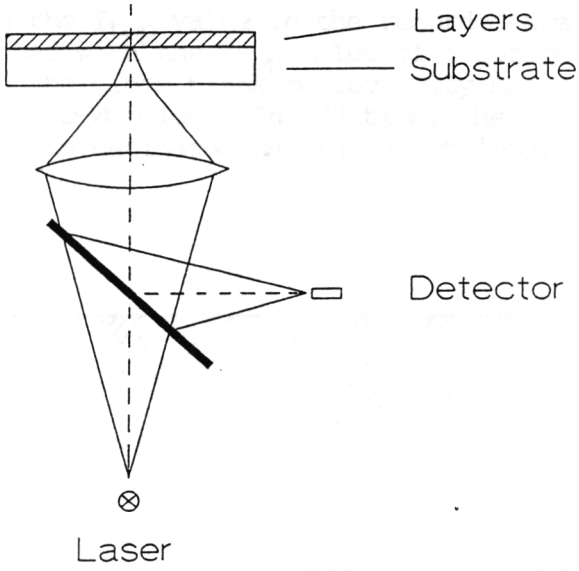


Fig B2.1: Schematic set-up for reflectivity measurements.

B2.1 The unrecorded CD-WO disc

The reflectivity R_o of a unrecorded, blank CD-WO disc can be measured routinely by comparing the I_o value of the disc to be investigated with the I_o value of a reference disc.
For calibration purposes we define: The reflectivity R_o of a blank glass substrate with only a gold layer on top of it, measured with a set up as described above, is by definition 96%. (substrate: n=1.51, gold layer: thickness > 100 nm, protective coating: allowed on top of gold layer).

B2.2 The recorded CD-WO disc

The requirements for the reflectivity of a recorded CD-WO disc are specified by:

$$\frac{R_{top} \equiv R_o * I_{top}/I_o}{R_o} > 0.65 \quad \text{(chapter 2.2 ad.8.4)}$$
$$> 0.70 \quad \text{(Red Book)}$$

The specification limits are visualized in Fig.B2.2.

The ratio I_{top}/I_o may differ significantly from 1 due to:

* the unrecorded groove level I_g being significantly lower than I_o. (depending on the groove geometry).
* the effect that recording has on the inter-pit groove reflection level (depending on the recording power).

A typical example of I_{top}/I_o vs recording power is shown in Fig. B2.3. The tolerance allowed on the ratio I_{top}/I_o depends on the obtained blank reflection level R_o.

R_{top} can be measured routinely by:

* comparing the I_{top} value in the recorded area of the disc to be investigated with the I_{top} value of a reference disc.
* measuring the discs blank reflectivity R_o in the same way as for unrecorded CD-WO discs. In addition, the I_{top}/I_o ratio of the disc to be investigated should be obtained. R_{top} then equals $R_o * I_{top}/I_o$.

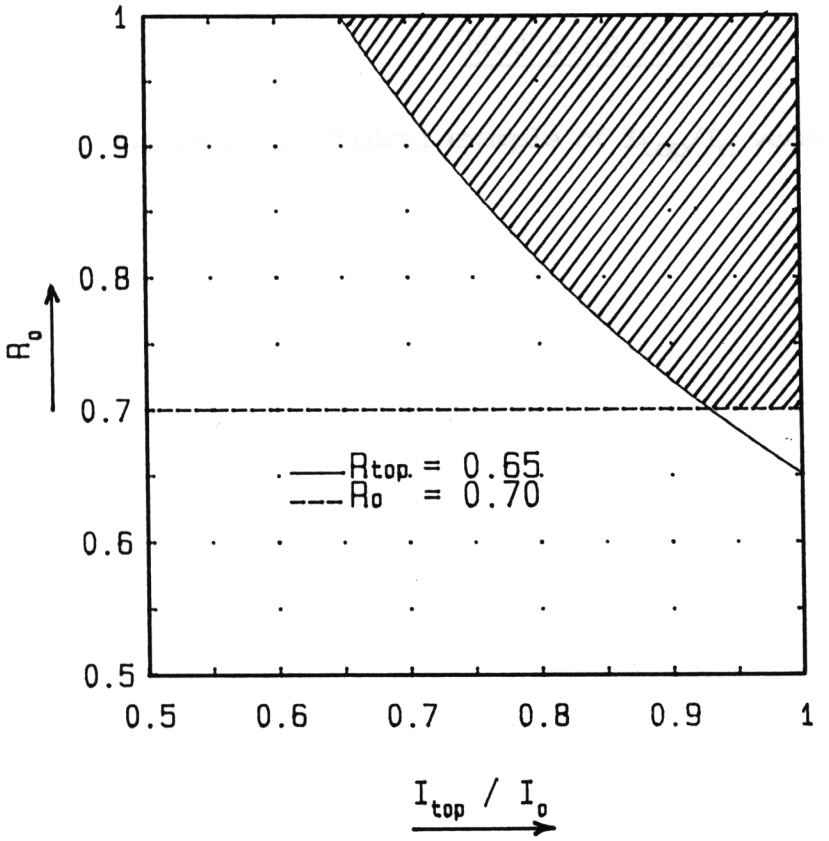


Figure B2.2: Reflectivity requirements.

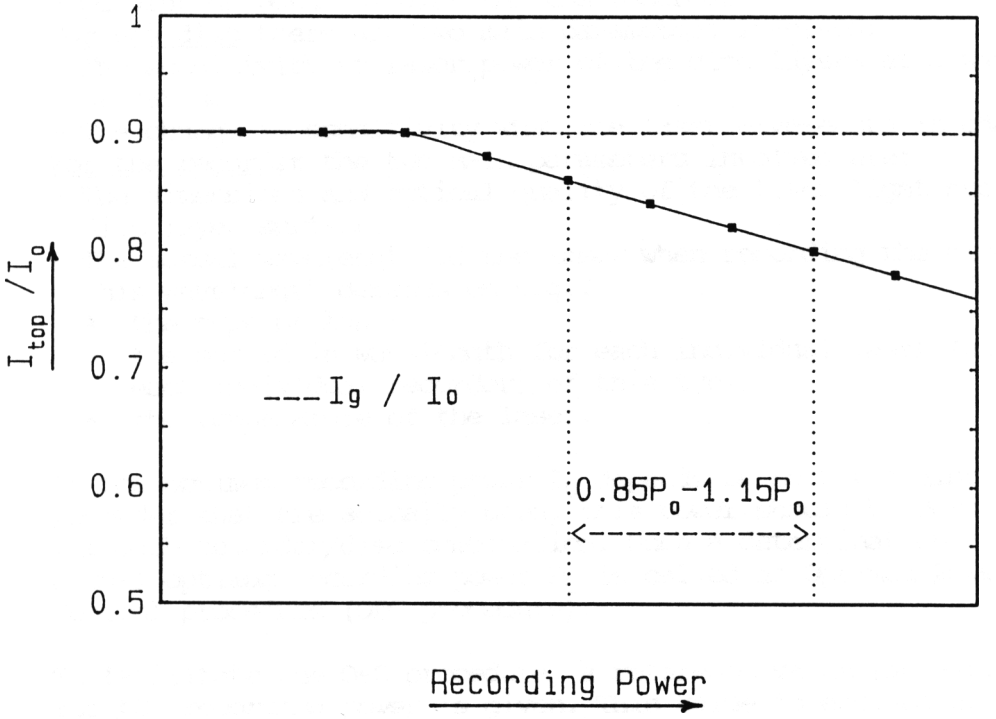


Figure B2.3: Typical example of I_{top}/I_o versus recording power.

B3. Optimum Power Control.

B3.1 Optimum recording power.

The laser power that should be used for recording a disc is dependent on both the disc and the recorder.
For the disc there are two main parameters involved:
- The sensitivity to laser power of the disc layers at a wavelength of 785 nm.
- The change in sensitivity when the laser wavelength is changed.

For the recorder the two main parameters involved are:
- The dimensions and optical quality of the laser light spot at the disc layer surface.
- The actual wavelength of the laser when recording the disc. This wavelength depends on e.g.:
  * the type of laser
  * the spread in wavelength for each individual laser (and so for each individual recorder) of this type.
  * the temperature of the laser.

As the optimum recording power P_0 depends on both the disc and recorder that are actually used, this power should be determined for each recorder/disc combination. Such a determination of the actual optimum recording power P_0 is called an Optimum Power Control procedure (OPC procedure).

To facilitate the OPC procedure, a reference value (an estimation) for the recording power is given. This value is encoded as special information in the ATIP during the Lead In Area (see chapter 4.4). This value is called the Recommended Optimum Recording Power for a wavelength of 785 nm at 25°C. As explained above, this value should not be used as the exact optimum recording power for the actual disc/recorder combination. How this value can be used in an OPC procedure is described in this Attachment in paragraph B3.4.

The OPC procedure should be performed in an area on the CD-WO disc that is specially reserved for this purpose: the Power Calibration Area (PCA, see chapter 5.3).
An example of such an OPC procedure in the PCA is described below.

B3.2 Asymmetry and optimum recording power.

For different recording powers, the asymmetry of the recorded EFM data is different.
By performing test recordings of EFM data with different recording powers, and measuring the resulting asymmetry in the HF signal, we can obtain the optimum recording power for the specific combination of disc and recorder.

B3.3 Measurement of asymmetry.

Using the definition of asymmetry in the Red Book directly, results in too complicated recorder electronics.
Therefore a different parameter is used as a representation of asymmetry.
This parameter β is based on using the AC coupled HF signal before equalization. We define: $\beta = (A_1 + A_2)/(A_1 - A_2)$ as the difference between the peak levels A_1 and A_2 (A_1+A_2), normalized to the peak-peak value (A_1-A_2) of the HF signal. See Figures B3.1 to B3.3.
Zero asymmetry of the measured HF signal results in $\beta = 0$.

It appeared that in practice a value of $\beta \approx 0.04$ results in optimally recorded signals. Therefore, $\beta \approx 0.04$ is used as the criterion for obtaining the optimum recording power P_0 (for a 'Recorder optical pick up' as defined in chapter 2.).

B3.4 Example of an OPC procedure in the PCA before recording.

- Go to the start of partition p of the Test Area of the PCA. This start time can be calculated from the number of already used partitions (noted in The Count Area) and the start time of the Lead In Area, see chapter 5.3.1.
- Start recording random EFM with different recording powers P at fixed time intervals. Use the value for the recommended optimum power (see chapter 4.4) as a reference P_{ref}:
  - recording power range: $P_{ref}-0.3*P_{ref} < P < P_{ref}+0.3*P_{ref}$ (boundary condition: $3.6 < P < 8.8$ mW)
  - 15 test recordings : $\Delta P = 0.043*P_{ref}$
    $\Delta t = 13.3$ ms = 1 ATIP frame
    (e.g. if P_{ref}=5.9 mW, then the recording powers P for the 15 test recordings are: 4.1, 4.4, 4.6, 4.9, 5.1, 5.4, 5.6, 5.9, 6.2, 6.4, 6.7, 6.9, 7.2, 7.4, 7.7 mW).
- Read out the recorded EFM data:
  Perform peak detection on the positive and the negative part of the AC coupled HF signal before equalization, and calculate β for each test recording.
- The optimum recording power P_0 is the power where $\beta \approx 0.04$.
- Go to the start of partition p of the Count Area of the PCA. This start time can be calculated from the start time of the Lead In Area, see chapter 5.3.2.
- Start recording random EFM with a recording power P_0, during 1 ATIP frame (1/75 seconds).
- End of the OPC procedure.

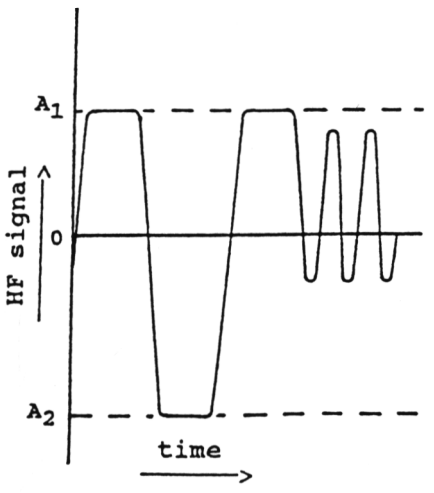


Fig.B3.1: $P<<P_0$

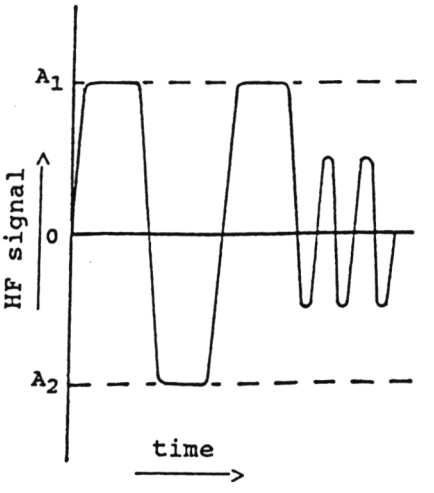


Fig.B3.2: $P \approx P_0$

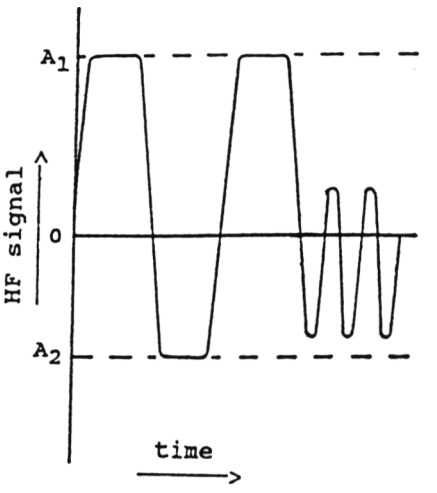


Fig.B3.3: $P>>P_0$

B4. Environment: operating and storage conditions.

Operating Conditions:

Rapid changes in temperature and humidity within these ranges may cause too large a deflection. Recovery times up to several hours have to be taken into account before reading from or recording in discs.

Recommendation:

* No condensation may occur on the disc.

Storage Conditions:

For storage and transport of discs before and after recording the following climatic tests are used to simulate typical conditions:

Dry Heat Test according to IEC 68-2-2 Ba

Temperature : 55 °C
Rel. Humidity: max. 50% at 35 °C
Storage Time : 96 hrs.

Cyclic Damp Heat Test according to IEC 68-2-30 Db

Temperature : 40 °C max.
Temperature : 25 °C min.
Cycles : 6
Rel. Humidity: 95%
Cycle Time : 12 + 12 hrs..

After these tests one should allow for some recovery time before reading from or recording in tested discs.

B5. Light fastness of the disc.

Light fastness of the CD-WO disc should be tested with an air cooled Xenon lamp and test apparatus complying with ISO-105-B02.

Test conditions:
* Black Panel Temperature : < 40°C
* Relative humidity: : 70 - 80 %

Disc illumination:
* Through the substrate, normal incident.
* Disc not packed, out of cassette.

Specification requirement:
All disc specifications (Orange Book Part II chapter 2) should be fulfilled, after illumination with a Xenon lamp corresponding with the European Wool Reference #5 (see ISO-105-B02).

Remark:
The change in color of the CD-WO disc is irrelevant for this test.

B6. Push pull amplitude and the Normalized Push Pull Ratio.

The definition of the Push Pull Amplitude in the Orange Book is basically the same as in the Red Book chapter 15. and 15.1.

* For the recorded part of the CD-WO disc, the definition is exactly the same as in the Red Book, and so the normalization is to I_{top}.

  $|I_1-I_2|/I_{top}$ at 0.1 μm offset = 0.04 - 0.07

* For the unrecorded part of the CD-WO disc no I_{top} value is available. I_g is chosen for normalization, because this signal is available when tracking in the unrecorded groove.

  $|I_1-I_2|/I_g$ at 0.1 μm offset = not specified.

There is no range specified for Push Pull amplitude before recording, because a more important value is the ratio of the Push Pull signals before and after recording. This is because the servo electronics have to deal with both recorded and unrecorded parts of a partially recorded disc, and so with two different Push Pull signals. As the dynamic range of the servo electronics is limited, the allowed ratio in Push Pull signals should be specified. Therefore the Normalized Push Pull Ratio (NPPR) is defined as:

$$\frac{|I_1-I_2|/I_g}{|I_1-I_2|/I_{ga}} = 0.5 - 1.0$$

where: I_g = groove level before recording.
I_{ga} = averaged groove level after recording: the averaged (τ=15 μs) HF signal before AC coupling. This signal is chosen for normalization because it is actually used by the servo electronics for tracking in a recorded groove.

Note:
For some CD-WO media, it is difficult to obtain Push pull values for the recorded disc within the specified range of 0.04-0.07. In practice, values somewhat higher than 0.07 will rarely cause trouble for recorder and player manufacturers. Therefore, CD-WO media with a Push Pull amplitude between 0.04 and 0.09 in the wavelength range of $780 < \lambda < 790$ will be permitted temporarily. As the Push pull range 0.04 - 0.07 is mentioned in the Red Book for all wavelengths $770 < \lambda < 830$ nm, media development should put strong effort in fulfilling this requirement.

B7. Measurement of the groove wobble amplitude.

The wobble amplitude in nm cannot easily be measured directly. However, it can be derived from the normalized wobble signal. The theoretical results for such a derivation are given below.

Relation between normalized wobble signal and wobble amplitude.

According to specification point 1.4.3, the wobble signal I_w can be seen as:

$$I_w = A * \sin(2*\pi*a/p) \qquad (1)$$

where a = wobble amplitude in nm (typical 30nm)
p = track pitch of the radial error signal
A = the peak value of the radial error signal

In figure B7.1 and B7.2 the parameters a, p, A and I_w are shown. The averaged center of the groove is taken as point 'o'. The groove has a peak displacement of 'a' (wobble amplitude) from the averaged center of the groove to the actual center of the groove. The normalized wobble signal can now be defined as:

$$\frac{I_{w\text{-rms}}}{(I_1-I_2)_{pp}} = \frac{I_w}{2*A*\sqrt{2}} = \frac{\sin(2*\pi*a/p)}{2*\sqrt{2}} \qquad (2)$$

where $I_{w\text{-rms}} = I_w / \sqrt{2}$ (3)

$(I_1-I_2)_{pp} = 2*A$ (4)

The definition in (2) is consistent with specification point 16.2. in chapter 2.1. The wobble signal (1) is not only dependent on the wobble amplitude "a", but also the track pitch "p". Due to normalization, dependencies on groove geometry, spot shape and optical aberrations have been eliminated.

Tolerances of the normalized wobble signal.
From the above formula for the normalized wobble signal, the tolerances as given in specification point 16.2 of chapter 2.1 can be converted to nm for a given track pitch of "p" = 1.6 microns.

Lower limit: 0.035 corresponds to 25 nm.
Upper limit: 0.050 corresponds to 36 nm.

Measurement suggestions.
The wobble signal and the push-pull signal should be filtered before measurement. The wobble signal should be filtered through a 10 - 30 kHz bandpass filter, the push-pull signal through a 5 kHz lowpass filter.
The wobble signal and the push-pull signal should be averaged over 10 seconds.

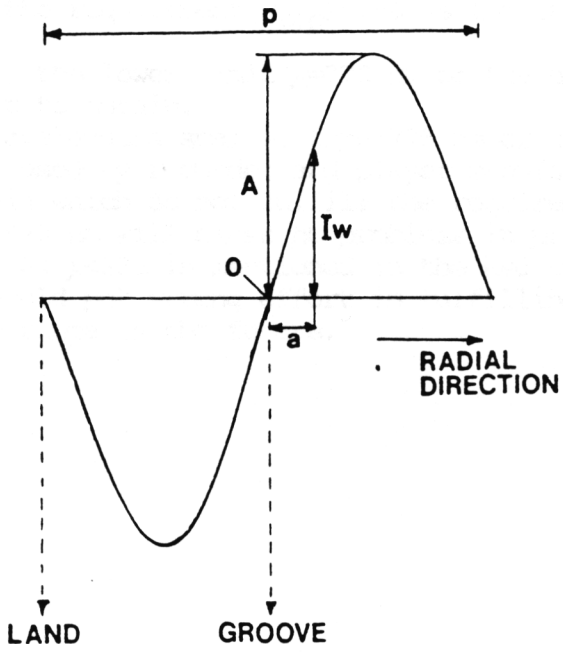


Figure B7.1: the radial error signal.

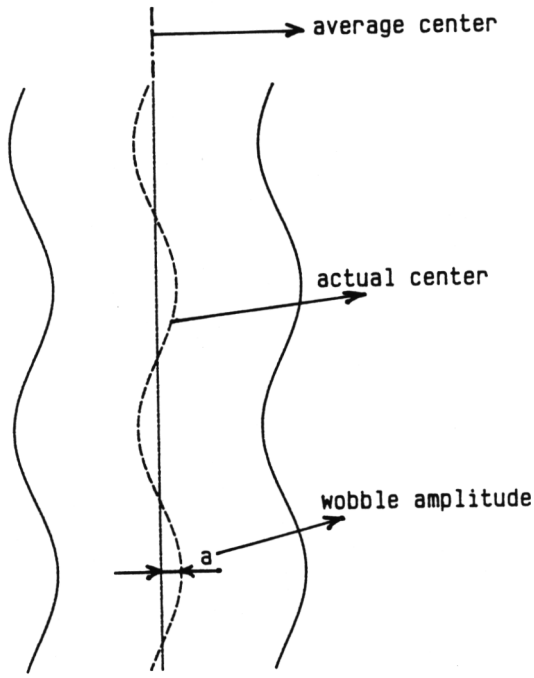


Figure B7.2: the groove wobble.

B8. R_{top} versus wavelength.

In principle, the requirement $R_{top} \geq 0.65$ is for the entire range $770 < \lambda < 830$ nm.
For some media, the lower limit $\lambda = 770$ nm or the upper limit $\lambda = 830$ nm is difficult to obtain.
In practice, wavelengths smaller than 775 nm or higher than 820 nm will be rarely used by recorder and player manufacturers.
Therefore, media which do not fulfill the requirement $R_{top} \geq 0.65$ for $\lambda < 775$ nm or $\lambda > 820$ nm will cause no problems in practice.
As the range $770 < \lambda < 830$ is mentioned in the Red Book, media development should put strong effort in fulfilling the requirement for the entire range in the future.

B9. Measurement of Jitter and Single Frequency Time Errors.

B9.1 Definitions.

Land jitter:
Land jitter is detected from the I_3 component of the unequalized HF signal and is the 1 sigma value of the time length and position variations measured from the rising edge to the falling edge of the unrecorded I_3 effect between consecutive pits.

Pit jitter:
Pit jitter is detected from the I_3 component of the unequalized HF signal and is the 1 sigma value of the time length and position variations measured from the falling edge to the rising edge of the recorded I_3 effect between consecutive lands.

B9.2 Measurement of jitter.

Measurement apparatus:
Use can be made of commercially available CD jitter meters or time interval analyzers for the measurement of jitter. The jitter meter or analyzer should include the following:
* A data slicer or adaptive level detector.
* Polarity switch (for land and pit jitter).

B9.3 Single Frequency Time Errors.

It is impossible to characterize all single frequency time errors which may occur on each disc. Therefore is specified that the maximum value in μs of any single frequency time error should be below the value given in Figure 2.2 of the Orange Book Part II. An example (which is common to both disc and player) is eccentricity. In practice this is often the main source of single frequency time errors originating from the disc.

B9.4 Read equalization.

Jitter measurements are done without read equalization.
In practical players and recorders we recommend however to use read equalization to improve system margins. Especially when Hybrid Discs are used, read equalization is strongly recommended. This is because the maximum allowed jitter for the Hybrid Disc is 40 ns instead of 30 ns (see chapter 11.3)

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